



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

NEW EDITIONS OF STANDARD WORKS.

1. PROUT ON THE NATURE AND TREATMENT OF STO-

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

16.

8vo. 14s. 6d.

17. ROBERTON ON PHYSIOLOGY AND DISEASES OF WOMEN. 8vo. 12s.

18. ACTON ON DISEASES OF THE URINARY AND GENERATIVE ORGANS. *Second Edition.* 8vo. 20s.

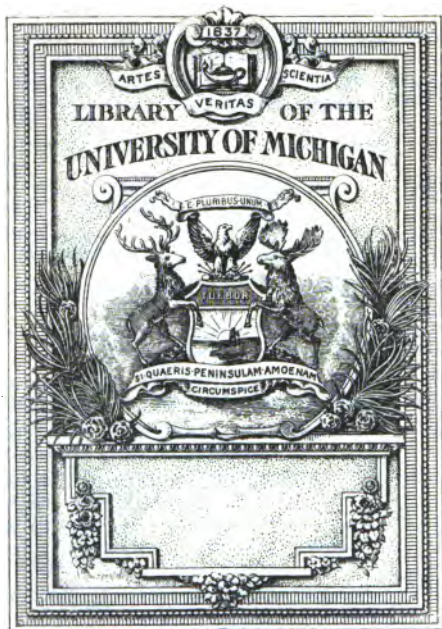
19. SKEY'S OPERATIVE SURGERY. 8vo. 18s.

20. BRANSBY COOPER'S LECTURES ON SURGERY. 8vo.

DISEASES OF CHILDREN. *Tenth Edition.* 15s.

OF THE LIVER. *Second Edition.*

CHURCHILL'S PUBLICATIONS



vo.

few

OF
Edi-

ion.

AT

IE-

RY.

HO-
6d.

DB-

ion.

IC

OF
ion.

ITS

22s.

cap.

Chem. &c. Co.

QD
39
G8
185

WORKS ON CHEMISTRY.

BOWMAN'S PRACTICAL CHEMISTRY, INCLUDING ANALYSIS;
with numerous Engravings on Wood. Fcap. 8vo. 6s. 6d.

BOWMAN'S HAND-BOOK OF MEDICAL CHEMISTRY. With
numerous Engravings on Wood. *Second Edition.* Fcap. 8vo. 6s. 6d.

FRESENIUS' INSTRUCTION IN CHEMICAL ANALYSIS.

QUALITATIVE. *Third Edition.* 8vo. 9s.

QUANTITATIVE. 8vo. 14s.

**FOWNES' CHEMISTRY, AS EXEMPLIFYING THE WISDOM
AND BENEFICENCE OF GOD.** *Second Edition.* Fcap. 8vo. 4s. 6d.

GALLOWAY'S FIRST STEP IN CHEMISTRY. Post 8vo.
cloth, 3s.

GALLOWAY'S MANUAL OF QUALITATIVE ANALYSIS.
Post 8vo. cloth, 4s.

GRIFFITHS' CHEMISTRY OF THE FOUR SEASONS. With
Engravings on Wood. Post 8vo. cloth, 10s. 6d.

**PROUT'S CHEMISTRY, METEOROLOGY, AND THE FUNC-
TIONS OF DIGESTION.** *Third Edition.* 8vo. 15s.

**BENCE JONES ON ANIMAL CHEMISTRY IN ITS RELA-
TION TO STOMACH AND RENAL DISEASES.** 8vo. 6s.

CHURCHILL'S MANUALS.

Fcap. 8vo. cloth, 12s. 6d. each Volume.

AGGREGATE SALE 55,500 COPIES.

ANATOMY.—ERASMUS WILSON, F.R.S.

CHEMISTRY.—Dr. FOWNES, F.R.S.

MATERIA MEDICA.—Dr. ROYLE, F.R.S.

MEDICAL JURISPRUDENCE.—Dr. TAYLOR, F.R.S.

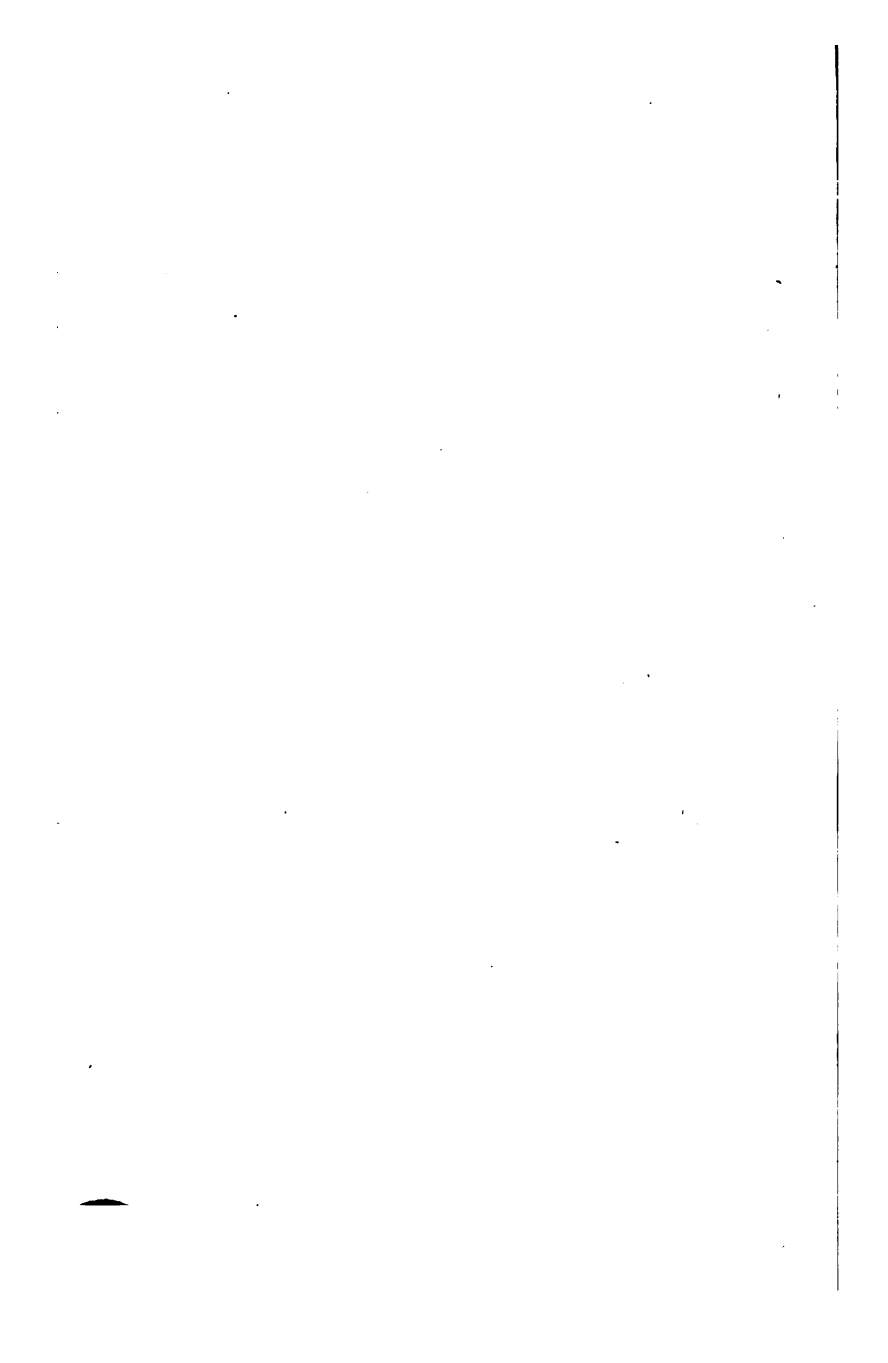
NATURAL PHILOSOPHY.—Dr. G. BIRD, F.R.S.

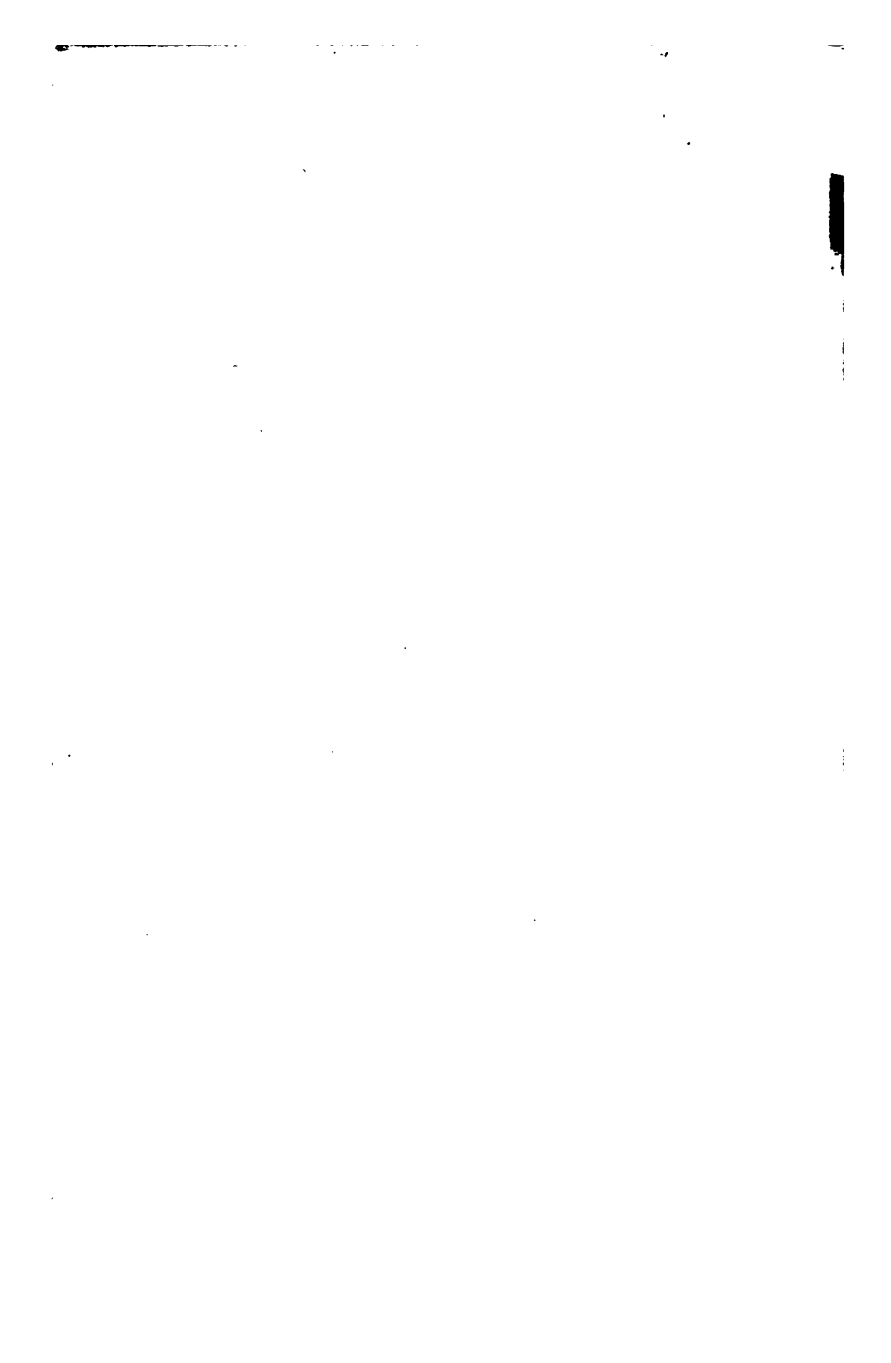
OPHTHALMIC MEDICINE.—WHARTON JONES, F.R.S.

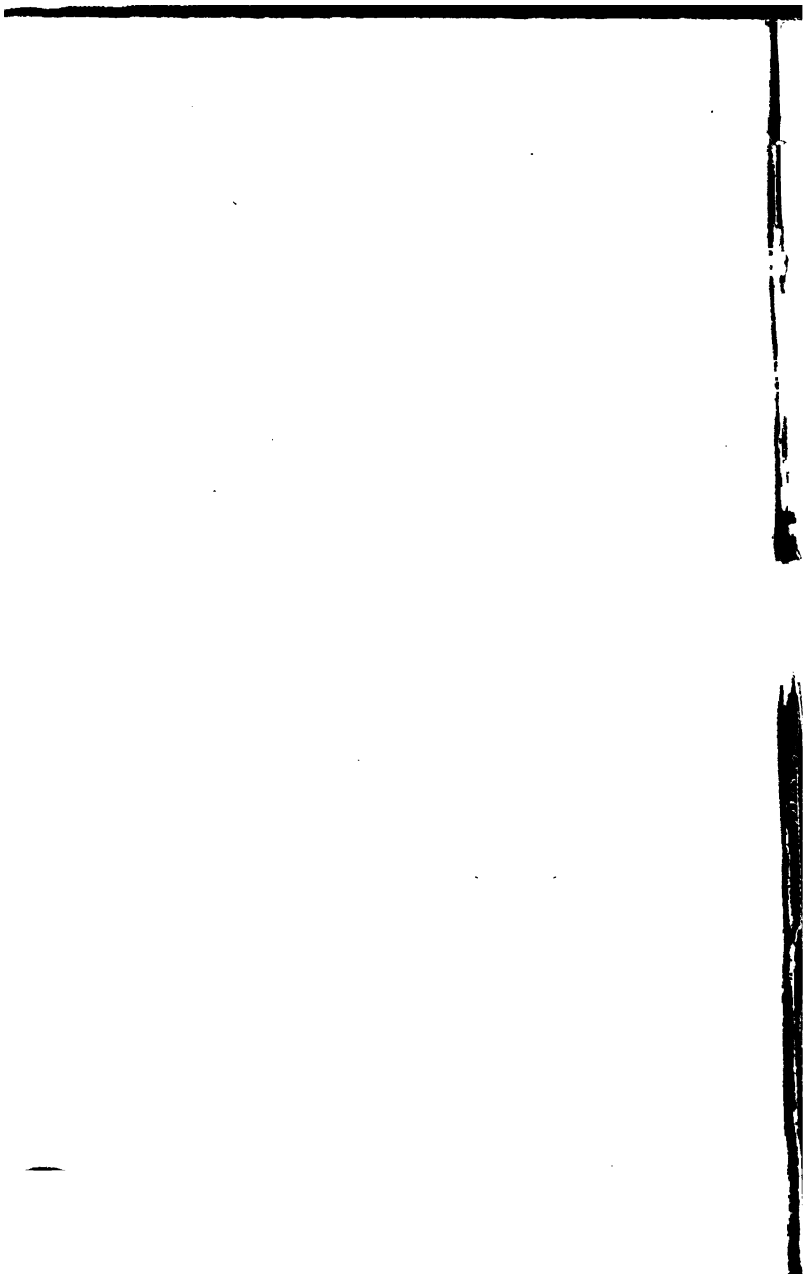
PHYSIOLOGY.—Dr. CARPENTER, F.R.S.

POISONS.—Dr. TAYLOR, F.R.S.

SURGERY.—Mr. FERGUSON, F.R.S.







CHEMISTRY
OF
THE FOUR SEASONS.

“WHILE THE EARTH REMAINETH, SEED-TIME AND HARVEST, AND
COLD AND HEAT, AND SUMMER AND WINTER, AND DAY AND NIGHT
SHALL NOT CEASE.”—Genesis chap. viii. verse 22.

CHEMISTRY
OF THE
FOUR SEASONS,
Spring, Summer, Autumn, and Winter :

AN ESSAY

PRINCIPALLY CONCERNING NATURAL PHENOMENA
ADMITTING OF INTERPRETATION BY CHEMICAL SCIENCE ;
ILLUSTRATING PASSAGES OF SCRIPTURE ; AND EXEMPLIFYING THE
WISDOM AND BENEFICENCE OF GOD.

By THOMAS GRIFFITHS,

LATE PROFESSOR OF CHEMISTRY IN THE MEDICAL COLLEGE OF ST. BARTHOLOMEW'S
HOSPITAL, AND ASSISTANT CHEMICAL LECTURER IN THE LABORATORY OF THE ROYAL
INSTITUTION OF GREAT BRITAIN ;

AUTHOR OF "CHEMISTRY OF THE FOUR ELEMENTS,"
"CHEMISTRY OF THE CRYSTAL PALACE," "RECREATIONS IN CHEMISTRY," ETC., ETC., ETC.



LONDON :
JOHN CHURCHILL, PRINCES STREET, SOHO.

MDCCCLIII.

LONDON :
G. J. PALMER, SAVOY STREET, STRAND.

PREFACE.

THE CHEMISTRY OF THE FOUR SEASONS on its first publication was honoured with favourable mention in several of the leading domestic and foreign scientific and literary periodicals; many valuable opinions were passed upon its merits by men of science whose personal friendship I have the pleasure to enjoy; others were forwarded to me by parties to whom I was only known through my humble endeavours as a public teacher and author, to contribute a small share towards the promotion of the great work of sound and useful scientific education.

I experienced much gratification in finding my essay thus recognized and rewarded. I have therefore devoted some months to its revision and enlargement, but have retained its original character and tendency, and I trust that it may now be found to merit the same approval which it gained upon its first appearance.

I have written expressly for the use of those unto whom the science of Chemistry is a sealed volume which they

885

Recd. Cass. M.P. 5-10-37

have been deterred from opening through the fear of finding its language too abstruse for perusal, or its tendency incompatible with religious studies; and I have endeavoured to bear in mind that in the interpretation of natural phenomena, "there is not so much required, any strength of imagination, or exactness of method, or depth of contemplation, as a sincere hand and faithful eye to examine, and to record the things themselves as they really appear."

During the progression of the Four Seasons, innumerable phenomena are presented throughout the boundless realms of the Creation: many of these are recorded in the sublime language of Holy Writ, and demand earnest attention from every philosophic mind, for their investigation cannot be incompatible with the study of the Scriptures, since both emanate from One Omnipotent Being to direct the humble approach of man to the throne of His goodness and mercy.

The extraordinary truths regarding natural phenomena which are disclosed by every department of experimental philosophy—particularly Chemistry—inevitably lead to a sincere and grateful recognition of the power and beneficence of God, which harmoniously blends with a devout and humble acknowledgment of immutable faith as commanded in His revealed will.

"Surely vain are all men by nature, who are ignorant of God, and could not out of the good things that are seen know Him that is; neither by considering the works acknowledge the Workmaster.

"But deemed either fire or wind, or the swift air, or the circle of the stars, or the violent water, or the lights of heaven to be the gods which govern the world, with whose

beauty, if they being delighted, took them to be gods, let them know how much better the Lord of them is, for the First Author of Beauty hath created them all.

"But if they were astonished at their power and virtue, let them understand by them how much mightier is He that made them.

"Wisdom is the principal thing, therefore get wisdom;" and for its acquisition, both spiritual and temporal, the student of science will be led to "search the Scriptures," and thus to imitate the example of the best and greatest philosophers, for Newton esteemed the Bible "the most authentic of all histories:" Hale said "none was like unto it for excellent wisdom, learning, and use:" Boyle considered it "a matchless volume, impossible to be too much studied or too highly esteemed:" and Locke pronounced it as "consisting of truth without any mixture of error for its matter."

I have reverentially selected a few of the beautiful passages of Scripture which refer to natural phenomena, and humbly endeavoured to interpret these through the medium of Chemistry, a science—to employ the words of Davy, my honoured master—"which has its moral and intellectual, as well as its common uses; its object is not only to apply the different substances in Nature for the advantages, comfort, and benefit of man, but likewise to set forth that wonderful history of Wisdom and Intelligence which is written in legible characters both in the heavens and on the earth."

Unto those who have not studied the science of Chemistry, I may say, in the words of the same true philosopher, "Its beginning is pleasure;" and when they have mastered its rudiments they will find "its progress, knowledge;" and

lastly, when they have attained its combinations and laws, and can venture upon the application of these to the interpretation of natural phenomena, they will confess "its objects, truth, and utility," and eminently calculated to inspire feelings of gratitude and reverence towards the Creator, "He that is excellent in power and judgment."

Chemistry is a science of truth, elicited by the examination of the habitudes and constitution of natural productions; even its smallest discoveries, and the tenor of their information, are of the greatest interest and importance for the elucidation of the phenomena of the Creation, and for the welfare of the arts of life.

For the proper study of Chemistry every fact must be obtained and demonstrated by experiment; and therefore with the view of rendering my explanations of various phenomena fully intelligible, I have given explicit directions for the successful performance of numerous illustrative experiments which do not involve the employment of costly agents or complicated apparatus.

Many portions of this work may appear to have but remote connexion with its immediate object, or, in other words, that the interpretations of the phenomena of Nature have occasionally ceded place to the manipulations of the laboratory, and these moreover detailed with needless minuteness; but the fact is otherwise.

Chemical experiments, illustrative either of natural or artificial phenomena, cannot be successfully performed unless the operator possess a large share of miscellaneous knowledge, and be skilled in its practical applications to the construction and management of the requisite apparatus and agents; for in the generality of instances the neglect

of apparently trifling matters will inevitably cause the failure of the desired results.

These technicalities are known to the proficient, but are unknown to the tyro ; I wrote descriptions of them, not for the former, but for the latter, and if he be successful through their means my object will be gained, and I shall willingly encounter the chance of being thought unscientific or verbose by those who are far advanced on the fascinating path of chemical science.

I have prefixed an extended analytical table of contents, and appended a list of the names of the discoverers, historians, and narrators of the principal facts which are embodied in the work, and also a full index, in order to facilitate reference to the several phenomena of the Four Seasons which admit of interpretation by the science of Chemistry, " and thus elevate our conceptions of the grandeur and goodness of HIM whose stately steps are traced in all the changes of the revolving year."

ERRATA.

Page 31, line 14, *insert* = 8×1 .

31, — 81, *for* 52 *read* 54.

247, — 19, *for* 3 *read* 2.

ANALYTICAL TABLE OF CONTENTS.

INTRODUCTION.

THE subject proposed, 1. Objects of the science of Chemistry. Phenomena of the Four Seasons. Object of the present work. Analysis, compounds and elements, 2—3. Ponderable and imponderable elements. Alphabetical list of ponderable elements. Metallic and non-metallic elements, 4. Four mechanical or physical states of ponderable matter. Names by which the elements are denoted, 5. Ordinary names of some of the elements. Elements mostly educed from their natural sources. Elements chiefly concerned in this inquiry. Properties of the metal iron, 6. No substances can be educed from iron. Iron is called an element. Properties of rock-salt. Two substances can be educed from rock-salt, viz., chlorine and sodium. Their properties. Rock-salt is called a compound. Properties of marble. Two substances can be educed from marble, viz., an invisible vapour and a white solid, 7—8. These admit of analysis and yield an invisible gas and a brilliant metal, viz., oxygen and calcium. Chemical nomenclature, 9. Marble a compound of carbonic acid and lime. Proximate and ultimate elements, 10. Properties of oxygen, carbon, calcium, carbonic acid, and lime, 11. Primary and secondary combinations. Analytical experiments always conducted by weight. Examples of the results so obtained 12.

Passage from Scripture illustrated by Chemistry. Ancient and modern state of science, 13—14. The atmosphere not an element but a mixture of oxygen and nitrogen. These can form five compounds, 15. Distinction between mixture and combination. Wisdom and beneficence of the Creator manifested in the constitution of the atmosphere, 16. Passage of lightning through the atmosphere produces an acid poison. Preservation of the animated creation by the hand of Omnipotence. Important discoveries at an early period of Chemistry. Original analysis of atmospheric air, 17. Recent analysis of atmospheric air. Water a compound of oxygen and hydrogen, 18. Properties of the latter. Three elementary gases. Remarkable example of chemical combination, 19. Anhydrous and enhydrous bodies. Tabular statement of the elementary and compound ingredients of the atmosphere. Ultimate elements of the atmosphere, 20. Proportion that the altitude of the atmosphere bears to the diameter of the earth. Tabular statement regarding the total weight of the atmosphere, 21. Pressure of the atmosphere upon a square inch of surface. Air, gases, and vapours can be weighed, and present important results. Illustrations of the meaning of the term specific gravity, 22—23. Passages from Scripture alluding to the beneficence of the Almighty in ordaining the presence of water around the globe, 24. Examination of the waters, viz., rain, spring, river, and sea water, 25. Properties of iodine, bromine, magnesium, and potassium, 26. Pure water never naturally presented. Water fit for beverage contains extraneous matters. Pure water can be artificially obtained and presents most remarkable properties, 27. Weight of elements deduced by the analysis of water. Hydrogen adopted as a standard of unity to which the combining weights of all elements and compounds are explicitly referred, 28. Illustrations of the important law of definite combinations by weight and the equivalent number of substances, 29—31. Illustrations of the extraordinary law of the combination of

volumes of gases and vapours. Properties of hydrochloric acid and ammonia, and presence of the latter in the atmosphere, 32—33. Chemical nature of the earths, viz., sand, clay, lime, and magnesia. Chemical names of the foregoing, which are proved to be metallic oxides. Properties of silica, 34. Ancient and modern employment of the term crystal. Insolubility of silica, 35. Presence of silica in the boiling fountains of Iceland. Properties of alumina, the chief constituent of clay, 36. Nature of white and coloured clays. Properties of calcia or lime, 37. Properties of magnesia. Natural compounds of the earths with acids containing non-metallic elements. Properties of sulphur, 38. Properties of phosphorus. Native compounds of lime, 39. Properties of carbonate of lime and sulphate of lime, 40. Properties of phosphate of lime. Earths and their compounds, saline substances and organic matters incorporated together constitute soils, 41. Tabular statement of the result obtained by the analysis of a fertile soil. Distinction betwixt inorganic and organic bodies. Organic bodies admit of ultimate analysis and present most extraordinary results, illustrative of the omnipotence of the Creator, 42. Insurmountable barrier presented to the synthetical operations of the chemist. Proximate principles educed from organic bodies, 43. Tabular statements regarding the weights of the ultimate elements carbon, hydrogen, oxygen, and nitrogen, educed by the ultimate analysis of the proximate principles of organic bodies, 44—45. General properties of the proximate organic principles called gum, sugar, starch, lignin, wax, gluten, gelatin, albumen, fibrin, and fat, 46. Remarkable phenomena revealed during the investigation of proximate organic principles. Organic substances may consist of the same elements and yet differ in properties, 47. Meaning of the term isomerism, 48. Proximate organic principles in addition to their chief elements, contain minute portions of others. Extraordinary fact regarding the ultimate elements of the human body, corroborating the testimony of Scripture con-

cerning the creation of man, 49. Chemistry investigates the functions of the animated kingdoms, throughout all their stages of growth, perfection, death, and decay, 50. Wonderful adjustments for the maintenance of the balance between the vegetable and animal creation. Influence of the imponderable upon the ponderable elements. Emanation of light from the sun and its separation into seven coloured rays, 51. Passage from Scripture regarding the rainbow. Probable physical cause of the phenomenon of the rainbow. Prismatic colours of light. Beneficence of the Almighty displayed in the chromatic nature of solar light. Chemical powers of the coloured rays of light, 52. Passage of light to the earth accompanied by heat. Importance of the universal presence and effects of heat, 53. Temporary expansion of solids, liquids, gases, and vapours by heat. Conductors, imperfect conductors, and non-conductors of heat, 54. The transparent atmosphere not directly heated by the solar rays, but indirectly from the heat absorbed by the opaque earth. Transparent water warmed by the heated atmosphere. Earth, air, and water are imperfect conductors of heat, or the animated creation would be destroyed, 55. Imponderable yet powerful agency of electricity. Natural display of electricity in the thunder-storm. Passage from Scripture regarding the thunder-storm. Conductors, imperfect conductors, and non-conductors of electricity, 56. Artificial excitation of electricity and its analytical power. All the foregoing phenomena present evidence of the power and goodness of the Creator, 57.

CHAPTER I.

Spring.

Reflections upon the beauty of this season, 58. Pheno-

mena attendant upon the germination and growth of seeds, 59—60. Dormant state of seeds when deeply buried in the earth. Soils adapted for the germination of seeds. Absorption of water by soils, 61. Physical attractive force between liquids and porous solids, called capillary attraction. Experimental illustration of capillary attraction by a cane, 62. Absorptive power of sand and mould, 63. Absorptive power and solubility of salt, 64. Natural agencies of capillary attraction in causing soils and rocks to bear vegetation, 65. Dampness in the walls of buildings. Porosity of Bathstone, and decay of sculptured work, 66. Chemistry applicable to Agriculture as regards an examination of the absorptive and retentive powers and the components of soils, 67. Experimental illustrations regarding the principles of chemical analysis, 68. Distinction between educts and products in analytical operations, 69. Tabular statement regarding the results of three analyses of soils, and remarks upon their fitness for the support of vegetable growth, 70. Absorption of water by soils affects their fertility. The nourishment of vegetables. Germination of seeds promoted by water, 71. Formation of springs of water in the earth. Fall of rain from the atmosphere. Physical cause of the accumulation of water in the atmosphere. Explanation and illustration of the phenomena of evaporation, 72. Water evaporates from the ocean, but its saline matters remain fixed, 73. The condensation of watery vapour in the atmosphere causes showers of rain to fertilize the earth. Scriptural passages alluding to these beneficial phenomena, 74. Porous and compact soils differ in fertility on account of differing in absorptive and retentive power of water. Soils attract aqueous vapour from the atmosphere. Experimental illustrations of the foregoing facts, 75. Saturation of air with aqueous vapour, and exposure of an artificially dried soil to its influence, 76. Absorptive powers of equal weights of different soils, dried at the same temperature and exposed to air saturated with aqueous vapour, 77.

Enormous weight of aqueous vapour naturally present in the atmosphere at all seasons. Uniformity in the constitution of the atmosphere through all vicissitudes of heat and cold, 78. Experimental illustrations regarding the mere expansion and contraction of a volume of atmospheric air by elevation and depression of temperature. The changes of volume thus produced are only mechanical, and not chemical, 79—81. Actual combustion in a volume of air produces chemical changes. Explanation of the support of flame by air. Animal respiration effects chemical changes upon air, educing its nitrogen, and producing carbonic acid by the union of its oxygen with the carbon of the animal body, 82. Experiments in illustration of the foregoing fact, 83. The results of respiration are mephitic, and the manner in which they are prevented from injuring vitality presents an example of the wisdom and beneficence of the Creator, 84. Detection of carbonic acid in exhaled air, 85. Future uses of carbonic acid throughout the Creation. Germination of seeds produces chemical changes upon the air analogous to the foregoing, 86. Vegetation has the miraculous property of decomposing the carbonic acid present in the atmosphere. Uncombined oxygen indispensable during germination. Germination prevented or morbidly accelerated in different gases. The natural atmosphere alone suitable for the welfare of vegetable and animal life. Power and goodness of God manifested in the constitution and preservation of the atmosphere, 87. Experimental processes for the analysis of air and the eduction of its chief elements oxygen and nitrogen. Tarnishing of heated metals in air technically called oxidation, 88. Oxide of mercury a source of oxygen, 89. Slow combustion of phosphorus in air produces phosphorous acid and educes nitrogen, 90—91. Properties of nitrogen. Volumes of oxygen and nitrogen present in a given volume of air, 92. Eduction and properties of oxygen, 93. Synthetical formation of air, 94—95. Consideration of the chemical phenomena of Spring resumed. March winds.

Homely proverbs, conveying philosophical truths regarding the phenomena of the seasons, 96. Classification of the forms of clouds. The region of clouds. Probable physical cause of clouds, 97. Scriptural passages regarding clouds. The pursuit of philosophical knowledge enjoined in the Scriptures, 98. Probable physical cause of the blue colour of the sky, 99. Blue colour of distant hills and mountains. Allusion made by the Saviour to the red appearance of the evening and morning sky, 100. Probable physical cause of the phenomenon and ancient proverb relating thereto. Probability of fair or foul weather foretold by the observance of the habitudes of the vegetable and animal kingdoms. Quantity of rain that falls in different parts of the world. 101—102. Rainless districts. Egypt fertilized by the inundations of the river Nile. Scriptural passage alluding thereto. Explanation of the causes which affect the quantity of rain in different localities. The phenomenon of the rainbow, and its probable physical cause, 103, 104. Coloured refraction of solar light by drops of rain. Refrangibility of the seven coloured rays of colourless solar light. The phenomenon of the double rainbow. A proverb regarding the rainbow, philosophically explained, 105, 106. Halo round the moon. All things demand equal attention from a true philosopher, 107. Importance of sound experiment and worthlessness of mere theory. The imperfect or bad conducting power of the earth as regards heat, is of importance to the welfare of the Creation and displays the beneficence of the Almighty, 108. Temperature of the earth in summer and winter, 109. Experiments regarding good and bad conductors of heat, 110—112. Examples of the bad conducting power of soils. Preservation of snow on Mount Etna by volcanic scorice. Extraordinary vital force displayed by seeds and plants, during their germination and growth, 113, 114. Supposed origin of the idea of the Corinthian capital. Extraneous matters enclosed by trees during their growth, 115. Precautions necessary in trans-

ANALYTICAL TABLE OF CONTENTS.

planting trees and shrubs. Plants poisoned by metallic and other preparations. The sap of plants, 116, 117. Evaporation of water from the leaves of plants, 118. Plants blighted by dry winds. Drooping of plants during a hot day. Absorption of aqueous vapour by the leaves of plants. The vegetable kingdom presents examples of the power, wisdom, and beneficence of the Creator, 119. Extraordinary varieties of the structure and functions of plants, shrubs, and trees. Bounteous gifts are not indiscriminately scattered from the hand of Providence, 120, 121.

CHAPTER II.

Summer.

Extraordinary increase of vegetable growth during this season, 122. Quantity of carbon revealed by the ultimate analysis of vegetable products. Weight of an average sized oak, and weight of carbon that it contains. Weight of sugar annually consumed in Europe, and weight of carbon that it contains. Chemical question to determine the source of the carbon in vegetables. Remarkable experiment upon the growth of a willow tree, planted in earth and supplied with water, 123. Water apparently the sole nutriment of plants. Accurate chemical investigation proves that plants derive their elementary carbon from the atmosphere, 124. Enormous amount of carbonic acid naturally present in the atmosphere, the sum for expressing its weight exceeding that of the number of human beings and of the seconds which have elapsed since the Creation. Quantity of carbonic acid exhaled by the respiration of human beings, 125. Tons of carbon present in the atmosphere. Wonderful provision

made by the Almighty for the future uses of the carbonic acid produced by animal respiration and other processes. Carbonic acid decomposed by plants. Mutual dependence of the animated kingdoms displays the power and goodness of the Creator, 126. Experiments regarding the decomposition of carbonic acid by growing plants, 127. Purificative action of growing plants upon vitiated air, 128. Paragraph by the discoverer of this wonderful fact. Vegetation will not proceed in the absence of carbonic acid from the atmosphere, 129. Observations by the president of a scientific society regarding the foregoing phenomena, 130. Experimental processes for the eduction of carbonic acid from the atmosphere. Decomposition of carbonate of lime by heat and acid, 131. Absorption of water by lime. Carbonate of lime heated loses weight. Test of the presence of alkaline substances, 132, 133. Phenomena attendant upon the exposure of a mixture of lime and water to the atmosphere. Carbonate of lime formed by the carbonic acid of the atmosphere, 134, 135. Apparatus, agents and process for the eduction of carbonic acid from carbonate of lime, 136—138. Decomposition of carbonic acid by potassium, production of oxide of potassium, and eduction of carbon that originally existed in the atmosphere. Pleasure derived from chemical pursuits, their refined and elevated tendency, 139, 140. Experiments regarding the expansion of solids, liquids, and gases during the heat of summer. Expansion of an iron bar, 141. Expansion of alcohol, 142. Principle upon which the thermometer is constructed, and graduation of its scale, 143. Principle upon which the barometer is constructed, and the manner in which it indicates fluctuations in the weight of the atmosphere, 144. Expansion of air by heat. Air and all æriform substances expand alike, 145, 146. Solar light influences vegetation. Plants grown in darkness have their functions deranged. The colours of flowers and fruits influenced by sunshine, 147. Vegetables blanched by

the exclusion of light, 148. Effects of the presence and absence of light upon the animal creation, 149. Solar light illustrates the omnipotence of the Creator. Impurities in the atmosphere injure the growth of plants, 150. Plants killed by acid vapours. The colours of flowers destroyed by acid vapours, 151, 152. Growth of plants in a confined volume of air cause it to contain a larger proportion of oxygen, 151, 153. Remarkable illustration of the preservation of plants growing in confined air. Tremulous motion of objects when viewed over a heated soil. Absorption and retention of heat by different coloured soils. The thermometer denotes the degree of heat that a medium can impart, and not the quantity of heat such medium may contain, 154—156. Substances at the same temperature do not contain the same quantity of heat. Experimental illustrations of the foregoing fact by the employment of oil and water. Meaning of the term capacity for heat, 157, 158. Experimental illustration thereof by similar weights of oil and water at 212° thawing different quantities of ice, 159—161. The capacity of substances for heat affected by changes of density. Heat evolved by beating lead and iron, 162. Heat evolved by mixing alcohol and water, 163. Heat evolved by the condensation of air, 164, 165. Construction of the air-pump, 166. Cold produced by the expansion of air, 167. Pressure of the atmosphere manifested. Production of an artificial and a natural mist. Heat contained in a volume of air, 168, 169. Diminution of the density of the atmosphere in proportion to its altitude from the earth, 170. Physical cause of the cold and snow upon the summits of lofty mountains. Harmonious adjustments of the powers and properties of matter by the hand of the Creator. No substances naturally found are capable of inflaming by solar heat, 171, 172. Sudden condensation of the atmosphere would destroy the globe by fire. Passages from Scripture recounting the Creation, and foretelling the destruction of the earth. The Hand of Providence protects

the animated Creation during the parching heat of summer. Clouds screen the earth from the sun, and relinquish showers for its refreshment. Fragrance after a summer shower. Coolness after a summer shower, 173, 174. Tabular statement of the evaporation of water during different movements and temperatures of the atmosphere. Salt lakes, or inland seas. The evaporation of water is attended by depression of temperature, 175. Practical applications of the fact for cooling apartments and beverages during the height of summer. Danger of wet clothes and water-proof clothing. Difference of sensation produced on the perspiring brow by a cambric and a cotton handkerchief. Thermometer affected by cold produced during evaporation, 176, 177. Construction of an instrument named the cryophorus for illustrating that water may be frozen by the cold produced during its own evaporation, 178, 179. Detection of watery vapour in the atmosphere by saline substances, 180. Construction of instruments named Hygroscopes for indicating the presence of watery vapour in the atmosphere. The weather-house and the monk and cowl. Incessant motion of the atmosphere productive of beneficial effects throughout Nature, 180. Physical cause of the sea and land breezes of tropical islands and coasts. Desiccation of the hay and corn harvest effected by the attraction of the atmosphere for watery vapour, 181—183. Water contained in sun-dried hay. Floods during hay harvest. Heating and firing of damp hay, 184. Analysis of the ashes of burnt hay educes silica and potassa therefrom, 185. Importance of this fact to the husbandman, as it teaches him the substances which must exist in soils to promote the growth of grasses, 186. Utility of the vitreous epidermis, or coating of straw. Silica is abundant in straw, but not in the ear of grain. Utility of potassa in soils. Exhaustion of soils by successive crops. Weight of ashes yielded by different kinds of straw, 187. Utility of straw for thatching haystacks and corn-ricks. Protection afforded by straw and dried leaves against heat and cold, 188.

Preservation of snow in the cavities of mountains by the Neapolitans. Forebodings of a thunder-storm, 189. The natural excitation of electricity presumed to be the physical cause of the phenomenon of the thunder-storm, 190. Accumulation of electricity in clouds, and its discharge therefrom as lightning to the earth and waters. Means of ascertaining the distance of a flash of lightning from the observer, 191. Extensive and limited flashes of lightning, and difference in the sound of thunder, 192. Peculiar odour prevalent during a thunder-storm depends upon the production of nitric acid. Showers of hail during thunder-storms. Passages from Scripture relating to thunder-storms and their concomitants, 193. Crystalline form of hailstones. Human emotions during a thunder-storm calmed by reflecting that it is directed by the will of God, 194. False philosophy of indifference to the works of the Creator. Precautions for personal safety during a thunder-storm, 195, 196. Discovery of the identity of lightning with electricity made by a true philosopher, 197, 198. Construction of conductors for protecting buildings from the effects of lightning. The water-spout, probably an electrical phenomenon, 199—201. Its dispersion by a sudden concussion of air. Minuteness of ships in comparison to the enormous ocean. Submarine volcanoes, 202. Escape of an excess of heat from the earth by radiation. Experiments in illustration of the reflection, absorption, and radiation of heat, 203—206. Difference between solar and terrestrial radiant heat, 207. The absorption of solar heat by different colours experimentally illustrated, 208. Omnipotence has ordained that the skin of the Ethiopian shall absorb heat powerfully, but not sustain the slightest injury, 209. Passage of Scripture relative to the sun stroke, 210. The rotation of the globe on its axis, and its inclined position in its orbit, producing the change of seasons, exemplify the power and beneficence of the Almighty, 211, 212.

CHAPTER III.

Autumn.

Phenomena of summer and autumn insensibly merge into each other, 213. Power and goodness of God exemplified by the phenomenon of dew. Probable physical cause of the deposition of dew upon the earth, and its productions. Dew only deposited upon objects that can derive benefit from its presence, 214. The Hand of Infinite Wisdom protects the earth and its productions from the chilling radiance of night. Tranquillity of the air essential to the perfect deposition of dew, 216. Shelter from radiation affects the deposition of dew, 217—219. Difference in temperature of sheltered and unsheltered grass. Warmth of a tent, 217—219. Plants protected from radiating by a covering of matting. Water frozen in warm countries by radiation. Water in dead organic bodies hastens their putrefaction, 220. The mere light of the moon will not induce putrefaction. Radiation proceeds from the earth, and not from the atmosphere. Plants chilled in hollows, but not on adjacent slopes, 221. Phenomenon of a mist at sunrise. Disappearance of mists and dew drops as the sun mounts higher in the heavens, 222. Pleasures and advantages of the just pursuit of Chemistry. Passages from Scripture regarding the blessings attendant upon the presence, and the miseries consequent upon the absence of dew. Deposition of dew affected by the course of the wind. Investigation regarding the form of a dew-drop, 223, 224. Adhesion of dew-drops and rain-drops to blades of grass. Spherical and spheroidal forms of aqueous drops, 225. Drops of water reposing on leaves and flowers, 226. Drops of water on the white plumage of a swan. Repulsions (so

called) of water from the feathers of aquatic birds. Honeydew on leaves, 227. Construction and use of an instrument named the Hygrometer, for measuring the quantity of aqueous vapour present in the atmosphere, 228—230. Degrees of atmospheric dryness denoted by the hygrometer, 231, 232. Aqueous vapour constantly present in the atmosphere. Hydration of a cubic foot of air at different temperatures. Transit of air over seas and arid sands, in the one case becoming anhydrous, and in the other anhydrous. Phenomena evident in Eastern climates. Reproof by the Saviour concerning the vanity of physical knowledge if not combined with perception of the excellency of faith, 233, 234. Accumulation of water as a lake on the summit of a mountain. Oppression felt on reaching the border of the lake, and absence of fishes therefrom. Aëration of water requisite for the respiration of fishes. Escape of air from water beneath the exhausting receiver of an air-pump, 235. Fishes die in unaërated water. Fishes breathe the air that water is capable of dissolving, 236. Overflow of the mountain lake, and aëration of its water during its fall to the valley, 237. Foam and roar of a waterfall depend upon air. Fall of water in a vacuum produces no foam, but a crashing sound. Fishes abound in aërated streams and rivers, 238. Beneficent provision made by the Almighty for removing the mephitic results of the respiration of fishes, by the action of aquatic plants. Decomposition of carbonic acid in water, and evolution of oxygen by the *conferva rivularis*, 239, 240. Principle of the construction of bird-fountains. Simplicity of apparatus for the pursuit of Chemistry, 241. The discovery of oxygen was effected by simple means, 242. Power of oxygen in supporting combustion. Aquatic plants derive their elementary carbon from carbonic acid contained in water. Air contained in the sea-weed named the *fucus vesiculosus*, 243. Beneficence of the Almighty in providing for the welfare of His creatures. Fishes become languid and sickly in artificial receptacles for water, unless aquatic

plants be placed therein. Sun-burn produced on the back of a silver fish. Solar radiant heat passes through water without elevating its temperature. Experimental proof of this remarkable fact. Burning focus obtained by means of a globular bottle filled with water exposed to the solar rays, 244—246. Air bubbles upon the surface of stagnant waters during summer and autumn, collected, and found to be inflammable carburetted hydrogen. The *ignis fatuus*, or Will-o'-the-wisp. Spontaneous light of the glow-worm and other insects, 247—249. Spontaneous light of vegetable productions. Luminosity of the ocean. Phenomena of phosphorescence. Necessity of burying dead organic bodies in the soil, 250. Poisonous æriform substances emitted by wet lands and marshes. Marsh-miasma of the fens of Lincolnshire and Essex. Malaria of portions of Italy. Insalubrious districts. Subtile deleterious matters resulting from the putrefaction of organic offal in crowded towns and cities. Nature of infectious and contagious matters unknown but can be destroyed by chemical agents, viz., nitric acid and chlorine. Eduction of nitric acid, 251—253. Action of nitric acid upon organic bodies and metals, 254, 255. Eduction of chlorine, 256—258. Destruction of colour and odour by chlorine. Method of fumigating large apartments or buildings by chlorine. Perfumes useless as disinfectants, 259—262. Disinfection by artificial heat. Aroma of flowers cannot be isolated from the atmosphere. Fragrance of flowering beans. Oppressive odour of flowers, 263. Force of atmospheric motion during the four seasons. Remarks concerning ancient and modern nitre. Passages of Scripture relating to nitre, 264. Sulphuric acid frequently occurs native. Sources of common salt, 265. Rock-salt, 266. Passages of the New Testament relating to salt. The corn-harvest of autumn, 267. Nutritive property of good bread. Proximate analysis of wheaten flour, and eduction and properties of gluten and starch, 268, 269. Solution of iodine a test of the presence of starch. Toasting

bread changes its starch into gum, 270, 271. Starch artificially changed into gum and sugar by chemical agents, and naturally by the germination of seeds. Physical cause of the circulation of the sap unknown, 272. Wheaten flour contains the phosphates of lime and magnesia. Utility of manuring wheat lands with crushed bones. Soluble and insoluble phosphate of lime, 273. Important office of the organic matter of bone as a manure. Vegetables secrete nitrogen from ammonia. Utility of quick-lime as an application to soils, 274. Gum and sugar of vegetables. Sources and properties of sugar. Carbon educed from sugar. Fermentation cannot ensue without sugar. Barley converted into malt, 275, 276. Fermentation of grape-juice. Carbonic acid produced during fermentation. Weight of carbonic acid and danger of suffocation by its vapour. Precautions to be taken before entering localities where it may be suspected to abide. Woody fibre or lignin the chief bulk of vegetables, 277, 278. Forest timber for the construction of dwellings and ships. Providence protects those that sail on the sea. Miraculous fact regarding the carbon in vegetable forms. Buoyancy of wood upon water, 279. Air removed from the pores of buoyant woods causes them to sink. Boat submerged by a whale. Wonderful diversity of forms assumed by lignin in vegetable productions, 280, 281. Saline earthy and alkaline matters of wood ashes. Carbonate of potassa, potassa, and potassium educed from wood ashes. Composition of glass for astronomical purposes. Examination of the ashes of a wood fire. Wood ashes render hard water soft, 282—284. Decomposition of wood by heat in closed vessels, produces vinegar or acetic acid, and educes charcoal. Lignin in the form of saw-dust admits of transmutation into bread. Lignin in the form of linen admits of transmutation into gum, starch, and sugar. Lignin in the form of cotton, by the agency of nitric acid, produces an explosive compound. Winter fodder of cattle contains lignin, and it undergoes important changes in the

digestive organs. Transmutations of proximate organic principles in living bodies are of most refined and wonderful nature, 285, 286.

Inexhaustible phenomena presented by the organic kingdoms afford magnificent examples of the wisdom and omnipotence of the Creator. Examination of the solid element of lignin, viz., carbon or charcoal, its indestructibility and antiseptic power. Weight of carbonic acid produced by the combustion of charcoal. Weight of carbonic acid compared with that of atmospheric air at the same temperature. Levity of carbonic acid as resulting from the combustion of charcoal exemplified by the inflation and ascent of a fire-balloon, 287—289. Utility of charcoal as fuel and its ancient employment for such purpose in metallurgical operations. Scriptural metaphor regarding the reduction of metals, and passages relating to brass and iron. Opinions of Scriptural commentators and experiments of chemists concerning brass 290, 291. Meteoric iron, malachite and calamine stone, 292. Distinctive characters and utility of metals. The bark of trees consists of lignin, a bad conductor of heat, 293. Trees artificially protected from cold by various forms of lignin. Temperature of trees in summer and winter. Foliage of trees a bad conductor of heat. Ripening and decay of fruits are sources of carbonic acid. Inorganic substances are unfit for food. An admixture of animal and vegetable food required for the sustenance of human life. Grain-bearing vegetables require cultivation, 293, 295. Cessation of wars and devotion to agriculture. Example presented by England. Philanthropic institutions and the science of medicine. Nitrogenous food imperatively demanded for the support of human strength, 296, 297. Changes sustained by food during the animal function of digestion. Gastric juice, chyme, chyle, venous, and arterial blood. Circulation and coagulation of the blood, 298—299. Little known regarding the animal functions. Confident assertion the mask of ignorant pride. Passage from Scripture relative to

the creation of man. Irreverent expressions regarding the recondite works of God are not employed by true philosophers. Produce of seeds in autumn, 300. Changes sustained by plants having fulfilled their destined functions, 301. Reflections upon the foregoing phenomena which are adduced in Scripture as emblematical of the resurrection of the dead, 302. Concluding phenomena of autumn exemplify the wisdom and goodness of the Almighty, 303, 304.

CHAPTER IV.

Winter.

The most remarkable phenomenon of winter is the transition of water into ice, 305. Anomalous expansion of water by cold or depression of temperature. Freezing-point of water. Degree at which water attains its maximum of density. Expansion of water above and below 40°, 306. Application of the foregoing experimental facts to the natural phenomenon of the freezing of a lake in winter. Cold water floats on warm water until ice be formed, and then it floats upon and protects the water beneath from chilling by the blasts of winter, 307. Temperature of water beneath ice perfectly congenial to the life of aquatic beings. Transcendent power and beneficence of the Creator exemplified by these habitudes of water with changes of temperature. Transition of water into ice not an abrupt phenomenon, 308. Some deep lakes are never frozen. Thickness of the barrier of ice rarely proportionate to the depth of the bulk of water. Tides and currents in rivers and streams cause them to resist congelation. Temperature of the ocean within the Arctic circle. Freezing-

point of sea water. Saline matter in water lowers its freezing-point, 309. Brine and water exposed to cold. Experiments regarding the phenomenon of the freezing of fresh water. Water at 33° lighter than water at 40°. Convective currents established throughout water when cold is applied to its surface. Ice although a compact solid floats on liquid water. Weight of a bulk of water, compared with a similar bulk of ice. Weight of a cubic foot of water, of sea water, and of ice, 310—313. Water adopted as a standard of unity in taking the specific gravities of liquids and solids. Statement regarding the specific gravities of various substances. Experimental illustrations of the fact that similar bulks of different substances have different weights or specific gravities. Great specific gravity of mercury, 314, 315. Formulæ for calculating specific gravities. Construction of a specific-gravity bottle. Sinking of an egg in water, and its floating upon brine. Construction and use of an instrument called the hydrometer, for ascertaining the specific gravities of liquids. Buoyancy of the human body, and of ships upon sea-water. Alcohol floating upon water, 316—318. Remarkable experiments regarding the floatation of liquids upon each other, 319—321. Specific gravities of the earths. Methods for ascertaining the specific gravities of solids, gases and vapours. Expansion of bulk sustained by a cubic foot of water during its congelation, 322—324. Rupture of bottles, pipes, iron tubes, and cast-iron bomb-shells, when filled with water, and exposed to frost. Beneficial effects produced throughout the Creation from the expansive force of freezing water. Degradation and decay of rocks by the same powerful agency, 325, 326. Sap of trees frozen during severe winter. Protection of new brick-work and water-pipes from flaking and bursting during frosty weather. Remarks concerning the freezing of water in a flask, and in the bulb of a cryophorus. Antiseptic power of ice exemplified in the case of the body of a mammoth discovered in a mountain of ice in Siberia; also as

regards frozen provision in Russia, and salmon as packed in Scotland, 327—329. Collection of ice from ponds in the vicinity of London. Construction of ice-houses or ice-wells for the preservation of ice, 330—332. Method of forming a lens of ice for collecting the rays of the sun to a focus, and kindling tinder therein. Necessity of breaking holes through the ice on fish-ponds. Provisions made by the power and beneficence of Providence for the existence and welfare of aquatic beings during long-continued frost. Important fact regarding the congelation of water. Frost-smoke of the Greenland seas, 333—336. Congelation of aqueous vapour exhaled from the lungs in frosty weather. Crystals of ice within foot prints, hoof marks, and wheel ruts on soils. Formation of ice at the bottom of rapid and impetuous streams, popularly called "ground ice." Probable physical explanation of this remarkable anomaly, 337—340. Passages from Scripture regarding the beautiful phenomenon of snow, and its preservation of the vegetation which it clothes. Great preservative power of snow against cold illustrated during a severe winter in Holland. Reflection of solar heat by light, and its absorption by dark coloured surfaces experimentally illustrated upon snow, 341. Construction of snow-houses by the Esquimaux. Red snow of the Arctic regions. Crystalline forms of snow-flakes, 342—345. Passages from Scripture regarding hail and hoar-frost, 346. Artificial production of a crystalline resemblance to hoar-frost upon branches and blossoms, by the sublimation of benzoic acid. Remarkable natural phenomenon of hoar-frost upon vegetation in the suburbs of London, 347—349. Formation and accretion of crystals upon solid objects influenced by the mechanical nature of their surfaces. Frost-work upon the interior of window panes and upon foot pavements during winter. Artificial and natural formation of icicles, 350, 351. Non-conduction of heat by water experimentally illustrated by causing it to boil only at the surface, and without thawing

a lump of ice placed a few inches beneath, 352. Remarkable phenomena attendant upon the elevation of water to its boiling point. Detection of the convective currents which ensue in water heated from below, 353. Apparatus for experimentally demonstrating the ascent of hot and the descent of cold water described, 354. Directions for its construction. Experiments regarding the degree of heat required for the ebullition of water to ensue, 355—357. The boiling-point of water liable to variation on account of fluctuation in atmospheric pressure. Depression of the boiling-point of water on a lofty mountain, and elevation of the boiling-point of water in a deep mine, 358. Beneficence of the Almighty in conferring these peculiarities upon water. Chemical composition of water not altered by physical changes of its state. Vapour of water the motive power of the steam-engine. Prolonged age of the improver of the steam-engine, 359. Conditions under which the boiling point of water is marked 212° on the thermometric scale. Experimental illustrations regarding the ebullition of water under reduced atmospheric pressure. Saline substances dissolved in water elevate its boiling-point, 360. Low boiling-points of alcohol and ether. Separation of alcohol from water by the process of distillation, 361, 362. Purification of water by distillation. Natural process of distillation affords water for the welfare of the animated Creation. Few have seen absolute or chemically pure water. Incorruptibility of pure water. Unpleasant odour of rain water as usually received and kept, 363. Different sensations produced by touching different bodies although at the same temperature. Intense cold produces dangerous effects upon the living body. Directions for the recovery of persons severely frost bitten or apparently frozen to death. Low temperature of the Arctic regions sufficient to freeze mercury, which contracts in freezing. Mercury and alcohol chosen for filling thermometers, 364, 365. A tranquil volume of air, at a high or low temperature does not readily

impart a sensation of heat or cold. Utility of double windows and doors in summer and winter, 366. Preservation of ice by the non-conduction of heat by wood and air. Experiment regarding the non-conducting power of air. Probable physical cause of the rapid expansion and contraction of a volume of air. Cooling of heated bodies in air. Convective currents in air detected. Remarks concerning the difficulty of ascertaining the specific gravities of æriform bodies. Heat and cold merely relative terms. The sensation of heat and cold produced by the same substance, at the same time and the same temperature, 367—369. Remarks concerning the decomposition of water by electricity. Experimental illustration of the decomposition of water by sodium and potassium, 370—373. Probable physical cause of volcanic eruptions on land and at sea. Arrangement of an apparatus for the decomposition of water, and the evolution of its elementary hydrogen by zinc and sulphuric acid, 374. Inflammability of hydrogen and production of water during its combustion, 375, 376. Definition of the term “catalysis.” Volumes of the gaseous elements, hydrogen and oxygen, contained in a drop of water, 377. Early discovery of the combustibility of organic productions. How the Creator revealed fire to man is unknown. The chemist is permitted to change, but not to destroy matter. Chemical changes attendant upon ordinary combustion. Production of water and carbonic acid and secretion of carbon from the latter by vegetation. Beneficence of the Creator regarding the foregoing phenomena, and the elements of the materials commonly employed as sources of light and heat. Scientific principles of the ordinary arrangement of fuel in a domestic grate, 378—380. Ascent of heated air, and cause of the pointed form of flame. Theory of the draught of chimnies. Mechanical diffusion of smoke, and chemical solution of steam in the atmosphere, 381, 382. Conditions for ensuring the escape of smoke from a fire, and the admission of air thereto,

383. Heated air ascends and accumulates at the ceiling of an apartment. Remarks concerning the ordinary injudicious construction of fire-grates. Radiation of heat from ordinary fires. Ascent and descent of smoke from a chimney, 384, 285. Proper situation for a fire-grate. Warming by closed stoves and heated air, 386, 387. Probable origin of coal; its chemical nature and extreme importance as fuel. Discovery and composition of coal-gas, 388, 389. Glowing of a cinder fire. Brightness of a fire during a frosty night. Blue flame on the top of the glowing fuel due to the combustion of carbonic oxide gas. Great heat required to produce flame, 390, 391. Bright and dark spots in a cinder fire present grotesque resemblances to various objects. Production and combustion of coke. Wisdom and beneficence of the Creator displayed in the association of coal iron-stone and limestone in the strata of the earth. Fire-damp of coal mines and choke-damp of quarries. Explosions of fire-damp in coal mines, and experiments of a philosopher for their prevention, 392, 393. Flame of a candle enclosed in a cage of wire gauze and rendered incapable of kindling the surrounding explosive atmosphere of fire-damp. The miner's safety-lamp explained and experimentally illustrated. Advantages conferred upon the welfare and prosperity of society by the employment of the safety-lamp, and the neglect of the erection of a national testimonial to the honour of its discoverer, 394, 395. Beneficence of the Almighty in providing for the protection of His creatures in all climes and seasons exemplified in regard to the texture of the skin, and fur of animals, the plumage of birds, &c. Change of the texture and colour of the clothing of animals of the same species inhabiting countries in different latitudes, 396, 397. Transition of snow and ice into flowing water, popularly called "thawing." Heat rendered latent during the liquefaction of ice. Experimental illustrations of the remarkable phenomena attendant upon the liquefaction of ice, and the

rise of the temperature of the resulting water to that of the surrounding atmosphere. Depression of temperature consequent upon the solution of saline substances in water, and the mixture of ice and salt. Removal of hard trodden snow from pavements, 398—401. Employment of freezing mixtures for the production of ice and hoar-frost. Congelation of water imparts heat to the surrounding atmosphere. Miraculous provision made by the Creator for mitigating the rigour of winter, 402, 403. Latent heat rendered sensible during solidification. Suspended crystallization and instantaneous crystallization of sulphate of soda, and preservation of its crystals, 404, 405. Reduction of the temperature of ice below 32° . Precautions regarding the graduation of the thermometer. A cold thaw explained on philosophical principles. Latent heat of steam. Increase of temperature during foggy weather. Condensation of water upon thick walls in certain changes of weather. Vapour of water, whatever be its temperature, invariably contains the same amount of heat. Beneficial results which ensue throughout the Creation by the operations of the immutable laws concerning the habitudes of water, with elevation and depression of temperature, 406—409. Magnitude of the earth, and the size of man. Passages of Scripture extolling the Omnipotence of God, and alluding to the insignificance of man. Concluding remarks, 410—413.

APPENDIX.

Containing the names of the discoverers, narrators, and exhibitors of the principal facts which are embodied in this work, 415.

CHEMISTRY

OF

THE FOUR SEASONS.

INTRODUCTION.

THE FOUR SEASONS present several phenomena which admit of interpretation by the science of Chemistry.

Scientific knowledge is extensively circulated, yet an impression is commonly entertained, that Chemistry is exclusively devoted to the performance of experiments with furnaces, crucibles, alembics, retorts, and receivers; acids, alkalies, salts, gases, and metals, which are often difficult and dangerous, and always more curious than useful.

It therefore appears improbable that such operations of the laboratory can be applied to an investigation of natural phenomena regarding the verdure of Spring, the heat of Summer, the produce of Autumn, and the cold of Winter; yet the fact is otherwise.

The full pursuit of Chemistry certainly requires complicated apparatus and subtile agents for the performance of experiments, which are occasionally hazardous, and invariably extraordinary; these, however, are not instituted for the gratification of mere curiosity, but for the discovery of valuable information. Facts regarding the powers and properties of matter, discovered by experiments in a chemi-

cal laboratory, constitute a key to the arcana of Nature, and reveal the principles of several phenomena, which, under the guidance of Providence, are perpetually active in maintaining the harmony and order of the Four Seasons.

Chemistry is a science of experiment ; its objects are truth and utility ; it ascertains the elements of things ; it examines the laws by which they are governed ; it applies each discovery to the increase of human knowledge and happiness ; it exemplifies the wisdom and beneficence of God.

Established upon the firm basis of inductive philosophy, the science of Chemistry maintains a rank of the highest intellectual and moral excellence ; its practice and study not only enlighten and adorn, but exalt and purify the mind, by faithfully demonstrating the miraculous workings of an Omnipotent and Eternal Power.

Behold the wondrous phenomena of the Four Seasons !

In Spring, fresh verdure clothes the earth, fair flowerets adorn its surface ; rippling streams wind throughout the fields ; fragile buds, tender leaves, and sweet blossoms bedeck the trees ; delicious odours float upon the air ; soft showers descend to fertilize the soil ; the glorious sun shines forth to cherish all nascent forms with its genial warmth ; the gorgeous rainbow spans the heavens to enhance the loveliness of the unfolding scene ; whilst ethereal light and heat augment in power unto the glow of Summer.

Then, limpid waters teem with countless forms of life ; luxuriant foliage crests each waving bough, and proffers cool shadow from the scorching sun ; clustering flowers vie in display of beauty and emission of perfume to the dazzling sky ; exuberant productions of smooth meadows and furrowed lands bend gracefully to the balmy gale, and ripen speedily for the scythe and sickle ; anon, the sultry noon-tide heat, the cool night dew, the lowering thunder cloud, and the vivid lightning, herald the advent of Autumn.

It comes, crowned with azure, and arrayed in russet robe, wreathed with brilliant flowers, and sparkling with aqueous

gems; laden with purple fruit and golden grain; it pours the abundant produce of the cultivated earth into the wide store-houses of the provident, to reward arduous labours, to realize anxious hopes, to afford generous support in time of need, and having thus fulfilled its beneficial purpose, slowly departs with declining radiance upon its destined course.

Humid mists appear; portentous clouds accumulate; impetuous winds blow cold; bright flowers fade, droop, and die; rustling leaves wither, fall, and decay, whilst glittering hoar-frost encrusts their parent branches; flowing waters are arrested in their rapid course, and fettered with hard transparent ice; fierce tempests rush throughout the darkened air, and spotless snow-flakes form the Winter mantle of the earth.

These four seasons, these definite periods of germination, of growth, of maturity, and of repose, familiar to all, yet unheeded by many, present the votary of Chemistry with inexhaustible scope for observation, experiment, and analogy to form the foundation of scientific truths, and to inculcate a devout reliance upon Him who promised, "while the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night shall not cease."

The object of the present work is to adduce a few of the principal phenomena of the four seasons which admit of explanation and illustration, through the medium of Experimental Chemistry, and as it is the science which teaches the composition of things, an introductory statement regarding natural productions, and the agencies unto which they are subject, will greatly facilitate all subsequent inquiry.

Many natural productions admit of chemical separation or analysis into two or more distinct substances, and it frequently happens that these do not admit of any farther analysis.

Substances which can be analysed, are called compounds; and those which cannot be analysed, are called elements.

Sixty-three ponderable elements are known and denoted

by the names which appear in the following alphabetical list; three imponderable elements are also known and denoted by the names of Light, Heat, and Electricity, to whose agencies all the others are subject.

ALPHABETICAL LIST OF PONDERABLE ELEMENTS.

1. Aluminum	22. Glucinum	43. Plutonium
2. Argentum	23. Hydrargyrum	44. Potassium
3. Arsenicum	24. Hydrogen *	45. Rhodium
4. Aurum	25. Iodine †	46. Ruthenium
5. Barium	26. Iridium	47. Selenion *
6. Boron *	27. Junonium	48. Silicium
7. Bromine †	28. Lantanum	49. Sodium
8. Cadmium	29. Lithium	50. Stannum
9. Calcium	30. Magnesium	51. Stibium
10. Carbon *	31. Manganese	52. Strontium
11. Cerium	32. Molybdenum	53. Tantalum
12. Chlorine †	33. Niobium	54. Tellurium
13. Chromium	34. Nitrogen ‡	55. Terbium
14. Cobaltium	35. Norium	56. Thion *
15. Columbium	36. Osmium	57. Thorium
16. Cuprum	37. Oxygen †	58. Titanium
17. Cybeleum	38. Palladium	59. Tungstenum
18. Didymium	39. Pelopium	60. Uranium
19. Erbium	40. Phosphoron *	61. Vanadium
20. Ferrum	41. Platinum	62. Yttrium
21. Fluorine †	42. Plumbum	63. Zirconium

Fifty-one of the ponderable elements are metallic, their names are not marked by either asterisk or obelisk; six are non-metallic and combustible, their names are marked thus*; five are non-metallic and incombustible, their names are marked thus†, they induce and support the combustion of the others; one non-metallic element, the name of which is marked thus‡, is neither combustible, nor a supporter of combustion.

Ponderable matter presents itself either in the form of a solid, a liquid, a gas, or a vapour, and is unknown, excepting in one or other of these four mechanical or physical states; the distinction between a solid and a liquid needs no remark; but the distinction between a gas and a vapour, requires explanation.

A gas is an aëriform substance, different from common air in its actual or inherent nature, and incapable of assuming either a liquid or solid state.

A vapour is an aëriform substance, different from common air in its actual or inherent nature, and capable of assuming either a liquid or solid state.

Given portions of solids, liquids, gases, and vapours, are technically denoted as masses, bulks, and measures, or volumes.

The ponderable elements present examples of the four mechanical or physical states of matter; the metals—with one exception—are solids; so are boron, carbon, iodine, phosphoron, selenion, and thion; hydrargyrum and bromine are liquids; hydrogen, nitrogen, and oxygen are gases; chlorine and fluorine are vapours.

The names of the fifty-one metals terminate in *um*; those of five non-metallic combustibles, which are solids, terminate in *on*; those of four non-metallic supporters of combustion, *i.e.*, one solid, one liquid, and two vapours, terminate in *ine*; and those of three non-metallic gases, *i.e.*, one combustible, one a supporter of combustion, and one neither combustible nor a supporter of combustion, terminate in *gen*.

All the foregoing names are foreign to ordinary language, and many of them are not to be found in any dictionary or lexicon; they have not been invented and conferred upon the elements for ostentation of etymology, but for facilitating construction of nomenclature, which is absolutely requisite for the elucidation of their properties in certain high and complicated departments of chemistry, and

it is an interesting and instructive study to trace each name to its etymon or root.

Several of the elements are popularly known by other names; thus, for example, in the alphabetical list, No 2 is silver, 4 gold, 16 copper, 17 zinc, 20 iron, 23 mercury or quicksilver, 27 bismuth, 40 phosphorus, 42 lead, 43 nickel, 50 tin, 51 antimony, and 56 sulphur, and these names are invariably employed in ordinary chemical discussions.

Most of the elements are educed from their natural sources by artificial means; few of them are presented in native purity, these are antimony, bismuth, carbon, copper, gold, iron, mercury, palladium, platinum, rhodium, silver, and sulphur.

Aluminum, bromine, calcium, carbon, chlorine, hydrogen, iodine, iron, magnesium, nitrogen, oxygen, phosphorus, potassium, silicium, sodium, and sulphur, are the ponderable, and light, heat, and electricity, the imponderable elements, that will demand most attention throughout the present investigation.

The ponderable elements unite to form compounds; these compounds unite to form complex compounds; and it is discovered that all known substances either consist of elements, or of their compounds, or of their admixtures, arranged according to definite laws of weight and measure.

The sense in which the term Element is employed and accepted in the science of Chemistry demands particular explanation.

Iron is a natural production; it is a hard solid metal, of a peculiar grey-white lustre; it tarnishes or rusts upon exposure to damp air; it is attracted by a magnet until it be made red-hot, it then becomes covered with a dark brittle scoria; it is malleable, ductile, and superior to all metals in tenacity; it softens at a white heat, and then one piece of the metal will adhere or weld to another similarly heated; at this heat it is readily combustible, and burns with the production of brilliant scintillations; it is infusible, except at a most intense degree of artificial heat.

All the foregoing, and many other properties of iron, are well known, and however these may be altered or disguised by submitting the metal to chemical experiments, at a certain point it will ultimately emerge from the ordeals in its original purity, without having yielded the slightest clue regarding the substances, of which it may consist.

Chemistry does not permit indulgence in hypotheses concerning the probable components of substances, it demands adherence to the results of the experiments which are made upon them; as, therefore, no two or more substances can be educed from iron, it must be considered as one specific substance, and must be called a rudiment or an element. By the employment of the term element, it is not dogmatically asserted that iron must be absolutely simple or undecomposable, because it resists all known chemical agents; the term element is employed conventionally to denote that the metal has not been experimentally proved to consist of two or more substances, or, in other words, that it has not been experimentally proved to be a compound; the term element, thus employed and accepted, is convenient and unobjectionable.

Rock-salt is a natural production, it is a solid, hard, brittle, transparent, colourless, fusible at a red heat, volatile at a white heat, incombustible, inodorous, soluble in water, and then forms brine, it has a pure saline taste, a strong antiseptic property, and is an indispensable addition as a condiment to all kinds of wholesome food.

Rock-salt, when submitted to chemical ordeals, cannot withstand their searching powers, but yields two new and distinct substances, namely, chlorine and sodium: therefore rock-salt must be a compound.

Chlorine is a vapour of a greenish yellow colour at common temperatures and pressures, hence the origin of its distinctive appellation—from the Greek *chloros*, *green*—it condenses into a liquid of a brilliant yellow colour; at low temperatures and extreme pressures, it is incombustible, it

is an inducer and a supporter of combustion; it has a most irritating and suffocating odour, and is instantly fatal to life; it has very extensive powers of combination with the metallic and non-metallic elements, and when the compounds so produced are not acid, they are generally styled chlorides.

Sodium is a metal soft and malleable at common, brittle at low, temperatures; its lustre resembles that of silver; it tarnishes in the air, it floats and burns on water, it burns when heated, its flame is orange coloured, its tarnish and the ash of its combustion are alike solid, acrid, caustic, and called soda, on account of being identical with a principle contained in a plant known as the *salsola soda*, or *kali*; hence the origin of the name applied to the metal, also the origin of the terms alkali, alkalies, and alkaline, by which soda and some other analogous non-acid substances are denoted.

As chlorine and sodium are the only two substances which can be educed from rock-salt, it is named chloride of sodium, to express its constitution with precision and brevity.

Chlorine and sodium, when subjected to chemical trials or experiments, yield no signs of components, they resist analysis or decomposition, they demand and they obtain the rank of elements.

Marble is a natural production; it is solid, hard, brittle, white, translucent, incombustible, inodorous, tasteless, and insoluble in water.

Marble when acted upon by certain chemical agents, soon parts with two new and distinct substances, the one an invisible vapour, the other a white solid: therefore marble must be a compound.

When the vapour educed from marble is submitted to chemical inquisition, it relinquishes two new and distinct substances, the one an invisible gas, and the other a black solid; the white solid educed from marble, when submitted

to chemical inquisition, yields the same invisible gas, and a brilliant metal.

The invisible gas educed by the analysis of the invisible vapour and of the white solid; is discovered to have the property of generating many acids; it is therefore named oxygen, from the Greek *oxus*, *acid*, and *gennao*, *I generate*; the black solid is discovered to be the pure combustible principle of charcoal; it is therefore named carbon, from the Latin *carbo*, *coal*; the brilliant metal is discovered to be a constituent of lime; it is therefore named calcium, from the Latin *calx*, *lime*. Chemistry derives many of its expressive technical names and terms from the copious stores of the dead languages,—this will be evident upon reference to the alphabetical list of elements, page 4; the science has also its own peculiar language or nomenclature for conveying, to a certain extent, an accurate idea of the particular elements which are concerned in the production of a compound, the chief characters of a compound, and the constituents of a complex compound.

For example, the invisible vapour educed by the first analytical operation upon marble is an acid, and consists of carbon and oxygen; it is therefore named carbonic acid; the white solid so educed is alkaline, and consists of oxygen and calcium; it is therefore named oxide of calcium.

When the metals, page 4, respectively numbered 2, 4, 16, 17, 20, 23, 27, 42, 43, 50, and 51, are called by their familiar names of silver, gold, copper, zinc, iron, mercury, bismuth, lead, nickel, tin, and antimony, the remainder of the names which terminate in *um* are understood to denote metals of more recent discovery; and in many instances when the name of a substance terminates in *a* it is understood to denote a combination of one or other of such metals with oxygen; thus, for example, sodium and calcium are metals, but soda and calcia are their oxides, the latter is identical with quick-lime; and the familiar name lime is preferably employed in ordinary chemical discussions to either of the

refined terms oxide of calcium or calcia. Lime, when combined with carbonic acid, is said to be carbonated; therefore the results of the first analytical experiments upon the composition of marble are accurately expressed by naming that substance carbonated lime, or more commonly carbonate of lime.

The second analytical experiments upon carbonic acid and lime prove them to be compounds: therefore the carbonate of lime, from whence they are educed, must be a compound of compounds.

In chemical nomenclature, although carbonic acid and lime are compounds, they are conventionally termed the proximate elements of the marble, or carbonate of lime, because they are nearest to, or next to, the hands of the experimenter, or are first educed by him, and are easily decomposable; but the three substances which they yield, are not farther decomposable; in this respect they are stubborn as iron, chlorine, and sodium, and are therefore distinguished as the ultimate elements of the marble or carbonate of lime, as they, in common with all others which have been enumerated, page 4, form the last, or the uttermost limits of chemical analysis.

It is highly probable that the sixty-three ponderable substances which are thus acknowledged as ultimate elements, are not atomic, or chemically indivisible; that many of them—the metals especially—will prove to be peculiar modifications of each other, or to contain the same inherent principles; but, in accordance with the logic of inductive science, they must all bear the title of elements until the light of analysis reveal their composition. Within the last fifty years, twelve substances were called elements exactly as sixty-three substances are now called elements, but a new analytic power was discovered and its energies directed upon them; they were decomposed, and reduced from the rank of elements to that of compounds. With this brilliant example steadfastly in view, Chemistry incessantly devotes its re-

searches to the discovery of another and greater analytic power, to be concentrated upon the substances that are now deemed to be elementary, and thus to effect their decomposition into simpler forms of matter. Oxygen is a gas, incombustible, but an inducer and supporter of all ordinary combustion; it is invisible, inodorous, tasteless, and respirable for a short time; it has an extended range of chemical affinity for most, if not all the other ultimate elements, producing with them a numerous and important series of compounds, some of which are acid, as carbonic acid, others alkaline, as soda,—oxide of sodium,—and others neutral, as rust—oxide of iron; the compounds of oxygen with other elements, when not acid, are generally called oxides.

Carbon is a combustible, usually black, moderately hard, inodorous, tasteless, infusible, and fixed in the most intense artificial heat, but then becomes sufficiently hard to cut glass; it produces numerous compounds of the utmost interest and importance, and occurs in a state of native purity as the brilliant transparent colourless diamond, which is the hardest form of matter.

Calcium is a metal of brilliant white lustre, highly inflammable, burning with a vivid red light, and producing lime.

The foregoing are only a few of the principal characters of the three ultimate elements, oxygen, carbon, and calcium; they will, especially the two first, be fully examined at a future period of this inquiry; a brief mention is next to be made regarding the chief properties of the two proximate elements, or the compounds called carbonic acid and lime. Carbonic acid is an invisible vapour; it has a slight sour odour and taste; it is perfectly irrespirable, and produces instant death; mingled with air it is a narcotic poison; by pressure and a low temperature, it condenses into the state of a transparent colourless liquid; this, at a lower temperature, congeals into the state of a snow-white solid; it is soluble in water; its compounds are numerous, and of great interest, and are usually called carbonates. Lime is a

white opaque solid, acrid, caustic, and alkaline; its other leading characters will be detailed in the sequel.

In chemical nomenclature, the union of two or more ultimate elements, is termed a primary combination; and the union of two or more primary combinations is termed a secondary combination; both ensue in consequence of an attractive force called chemical affinity, which disposes substances having the most opposite characters to unite, and to produce compounds in which the original characters of the substances are completely disguised, as illustrated in the instances which have been detailed.

All chemical experiments regarding the composition of substances are performed with the utmost accuracy, and the results certified by a standard balance; and it is discovered that all primary and secondary combinations result from the union of their respective ultimate and proximate elements in definite proportions by weight.

For example, analysis of 100 parts by weight of chloride of sodium educes 60 parts by weight of chlorine, and 40 parts by weight of sodium; these are the ultimate elements of a primary combination.

The analysis of 100 parts by weight of carbonate of lime educes 44 parts by weight of carbonic acid, and 56 parts by weight of lime; these are the proximate elements of a secondary combination.

Then, the analysis of the 44 parts by weight of carbonic acid educes 32 parts by weight of oxygen, and 12 parts by weight of carbon; the analysis of 56 parts by weight of lime educes 16 parts by weight of oxygen, and 40 parts by weight of calcium; these are the ultimate elements of the secondary combination.

When the results of chemical experiments upon elements and compounds are detailed in writing, the direct use of a number indicates the part, or the parts by weight of the substance, or the substances, under examination, the names of which are stated either before or after the number; the

former plan is most convenient, as a preposition may be omitted; the algebraical symbols of addition, multiplication, equality, &c., are employed in their usual significations, and by these conventional forms tautology is avoided.

Accordingly, the foregoing facts relating to the composition of chloride of sodium, carbonate of lime, carbonic acid, and lime, may be more concisely stated in the annexed formulæ:—

Chloride of sodium, $100 = \text{chlorine } 60 + \text{sodium } 40$;
 carbonate of lime, $100 = \text{carbonic acid } 44 + \text{lime } 56$; car-
 bonic acid, $44 = \text{oxygen } 32 + \text{carbon } 12$; lime, $56 = \text{oxy-}$
 $\text{gen } 16 + \text{calcium } 40$.

The above substances elicited by proximate and ultimate analysis can be induced to combine, and they will only do so according to the definite weights in which they were excited to separate, for an immutable law of definite weight governs every analytical and synthetical operation.

Chemistry thus tending to the discovery of the elements of natural productions, and the definite laws by which their attractions are governed, unfolds numerous illustrations of the Scriptural truth, that “a just weight and measure are the Lord’s; that a just weight is His delight; that He comprehended the dust of the earth in a measure, and weighed the mountains in scales and the hills in a balance.”

Chemistry experimentally investigates the nature and properties of all substances which come within its scope, and proves their harmonious adaptation to the fulfilment of the ends for which they were created; vast treasures of inestimable value and practical utility are thus constantly revealed, and faithfully applied to increase the welfare and comfort of mankind, and above all, reverently adduced as examples of the wisdom and beneficence of “the Giver of every good and perfect gift.”

Ancient schoolmen, vain-glorious of their abstruse metaphysical contemplations, scorned to institute intelligible practical investigations concerning the miraculous and beau-

tiful phenomena of the vast and boundless creation ; they wasted their talents in vague arguments upon the subtleties of words, rather than devoted them to sound experiments upon the utility of things ; wise in their own conceit, they perverted the truth, mystified the simplicity, and concealed the beauty of physical causes, by false theorems, acute sophisms, and absurd hypotheses ; to render all these tenable, they capriciously assigned each form of created matter a certain property accordant with their preconceptions, and dogmatically pronounced it to be actual or absolute.

"The wondrous works of God," were thus wilfully disregarded through the vanity of men "who darkened counsel by words without knowledge."

The dogmas of the learned few, fettered the intellect of the unlearned many, none of whom dared to question their validity by a direct appeal to trial ; they were accordingly slavishly handed down from generation to generation, from age to age, all men implicitly believing, amongst other absurdities, that air, water, earth, and fire, were absolute elements, neither composable nor decomposable, until the close of the seventeenth century, when Chemistry shattered all such polemical fetters by the irresistible force of philosophical experiment.

Chemistry proves that air, water, earth, and fire, are not absolute elements, that the three first are composable and decomposable, and that the fourth is producible when they are caused to undergo sudden and violent changes.

Chemistry employs the term elements as a humble confession of its own limited power of research, not as an arrogant dogma that such substances must absolutely be the primordial atoms at the command of Omnipotence.

The enlightened state of Chemistry in modern times affords a brilliant contrast to its gloomy condition in by-gone ages, when but a scanty number of its agents and principles were known or understood, and were constantly directed to sordid attempts at the transmutation of metals,

or presumptuous darings at the fabrication of an elixir of immortality.

Under Providence, air, water, earth, heat, light, and electricity, are agents perpetually active throughout the four seasons in ministering to the existence and support of the animated creation, and many of the phenomena presented by such ponderable and imponderable forms of matter, fall strictly within the limits of chemical investigation.

For example, Chemistry experimentally proves that the ambient air, or the atmosphere, is not an element, for its vast volume consists principally of two gaseous elements, namely, oxygen and nitrogen.

The element nitrogen is invisible, inodorous, tasteless, incombustible, an absolute non-supporter of combustion and respiration; in these respects it is most strikingly and diametrically opposed to oxygen; the name by which it is denoted, derived from the Greek *nitron*, *nitre*, and *gennao*, I *generate*, alludes to the fact, that under certain conditions it can generate or produce the solid substance called nitre.

Analysis of 100 parts by weight of atmospheric or common air educes very nearly 23 parts of oxygen, and 77 parts of nitrogen.

Chemistry discovers five other substances, consisting of the same gaseous elements as shown in the annexed statement:—

1. Nitrous oxide . 100 = oxygen 36.40 + nitrogen 63.60
2. Nitric oxide . 100 = oxygen 53.33 + nitrogen 46.67
3. Hyponitrous acid 100 = oxygen 63.20 + nitrogen 36.80
4. Nitrous acid . 100 = oxygen 69.60 + nitrogen 30.40
5. Nitric acid . 100 = oxygen 74.10 + nitrogen 25.90

The first is a neutral invisible vapour; its neutrality is expressed by the term oxide, although it contains oxygen, which often generates acids; the weight of this element is inferior to that in the second, a fact denoted by the termination *ous*.

The second is a neutral invisible gas; its neutrality is ex-

pressed by the term oxide, although it contains a weight of the element superior to that in the first, a fact denoted by the termination *ic*.

The third is an acid liquid, of a dark green colour, it contains a weight of oxygen superior to that in the second, yet inferior to that in the fourth, this fact is taken as a distinctive character, and denoted by the prefix *hypo*, signifying under, or inferior.

The fourth is an acid vapour, of a dark orange colour; it contains a weight of oxygen superior to that in the third, yet inferior to that in the fifth, a fact denoted by the termination *ous*, as in the case of the first oxide compared with the second.

The fifth is an acid solid, transparent, and colourless; it contains a weight of oxygen superior to that in any of the others, the fact of this superior or maximum weight is denoted by the termination *ic*, as in the case of the second oxide compared with the first.

These five substances are poisons, although they contain the same elements as the atmosphere which is the pabulum of life.

This apparent contradiction or anomaly admits of satisfactory explanation, for Chemistry discovers that the elements, oxygen and nitrogen, are merely mechanically mingled to constitute salubrious common air, but are actually chemically combined to constitute the five poisonous substances; and that, whilst the mechanical mixture of the two elements is bounteously presented for the support of the animated creation, their five chemical combinations, with one exception, are never naturally presented, but are artificially formed in laboratory operations. The Creator, in his omnipotence and omniscience, has ordained the gaseous elements of the atmosphere to be incapable of combining under all ordinary vicissitudes which it sustains during the four seasons; so that they remain intimately and uniformly blended together, to constitute the principal volume of the first and last food of life.

During the extraordinary commotion produced throughout the atmosphere by the thunder storm, as the lightning darts forth in terrible display of natural electricity, the science of Chemistry discovers that the vivid flash of ethereal fire suddenly induces the aerial elements in its direct path to combine, and produce nitric acid poison; but this result is miraculously restrained by Providence within the limits of the lightning flash, and is not permitted to extend throughout the entire volume of the atmosphere, or inevitable would be the destruction of every living thing. The comparatively minute portion of nitric acid poison which is formed, even during a protracted discharge of lightning through a limited portion of the atmosphere, is soon diffused to a highly attenuated extent amid the enormous remainder of its untainted volume, and neutralized by a certain alkaline vapour which is ordained to ascend and thus deprive it of virulence. The hand of Omnipotence thus preserves the animated creation whilst it is surrounded by the elements of destruction; true indeed, is the solemn warning, that "in the midst of life we are in death."

Chemistry did not rank as a science until the close of the seventeenth century, and even at that period its researches were unavoidably conducted with apparatus of imperfect construction, and agents not absolutely pure; notwithstanding such serious obstacles to the attainment of accuracy, several philosophers, with praiseworthy diligence, discovered a vast number of generally correct facts, many of these remain valid, although submitted to the perfect apparatus and pure agents with which the science is now furnished.

At the time, and under the disadvantages aforesaid, the analysis of atmospheric air was first performed, and the result which was discovered, appeared to sanction a statement that a volume of air equal to one hundred parts by weight, consisted of twenty-three parts of oxygen, and seventy-seven parts of nitrogen, both gaseous elements, being intimately and uniformly blended.

Recent and refined analysis of atmospheric air, certifies that the above per centages of its two elements approximate the truth, taking into consideration the conditions under which they were obtained, and the absence of knowledge regarding other substances of later discovery. Guarded from every source of error by the utmost exercise of human skill, analysis of one hundred parts by weight of atmospheric air proves it to contain twenty-three parts and thirty-two hundredths of oxygen, seventy-five parts and fifty-five hundredths of nitrogen, one part and three thousandths of watery vapour, and one-tenth of a part of carbonic acid vapour. Carbonic acid was unknown at the time of the original analysis of atmospheric air, and although watery vapour was known, its minute quantity easily eluded detection in the limited volume of the air that could be subjected to experiment; thus, the one substance being unknown, and the other unheeded, the inference was drawn, and the statement made, that the atmosphere consisted solely of oxygen and nitrogen gases.

Carbonic acid, when analytically isolated from the atmosphere—or other sources in which it exists—is a vapour fatal to animal and vegetable life, and is materially heavier, volume for volume or measure for measure, than either oxygen or nitrogen gases, or the vapour of water, and yet as it occurs mechanically mingled with these three attenuated forms of matter to constitute the atmosphere, it is absolutely essential to the welfare of the animated creation, and never subsides from the atmosphere to form a mephitic stratum upon the surface of the earth; indeed, all the constituents, though remarkably differing in their relative weights, never separate from each other, but remain intimately blended, in obedience to the command of their Creator.

Chemistry discovers that water is not an element, but a compound, and that one hundred parts by weight of the substance in either of its three physical states—liquid, solid,

and vapour—invariably contain eighty-eight parts and nine-tenths of oxygen, and eleven parts and one-tenth of hydrogen.

Hydrogen is combustible, but a non-supporter of combustion; it is invisible, inodorous, tasteless, respirable for a few seconds, during which it has the curious power of changing a bass voice to a treble; it has an extensive range of affinity for non-metallic elements, but a limited range of affinity for metallic elements; all its compounds are of great importance; its name, which is derived from the Greek *hudos*, *water*, and *gennao*, *I generate*, alludes to the fact that it produces water when it enters into combination with oxygen; it is the lightest form of matter.

Oxygen, nitrogen, and hydrogen, are the only elementary gases that are known, and they are often distinguished as the three gazolytes.

The union of oxygen and hydrogen in the foregoing definite proportions by weight, affords an excellent example of the extraordinary and total concealment of the original properties of substances when they enter into chemical combination. Thus, oxygen is incombustible, but will support combustion; hydrogen is combustible, but will not support combustion; both elements maintain their gaseous state, whether isolated or mingled, and manifest no tendency to assume either a liquid or solid state at any degree of cold or pressure.

When these elements in mechanical mixture, are induced to enter into chemical combination, they produce an invisible vapour; it is not combustible, it will not support combustion, it can assume the state of a transparent colourless mobile liquid, at a moderate degree of cold, and this liquid can assume the state of a transparent, colourless, hard solid, at a lower degree of cold; the compound in all its three physical states is inodorous, tasteless, innoxious, absolutely essential to the existence of the animal and vegetable kingdoms; it is, in fact, water, or chemically speaking, a neutral

oxide of hydrogen, although rarely so denominated; as the term might be deemed pedantic. When water enters into chemical combination with other substances, they are said to be hydrated or enhydrous; and when substances do not contain water, either chemically combined or mechanically mingled, they are said to be anhydrous. By the imponderable agency of solar heat, water is converted into light invisible vapour, in which attenuated state it intermingles with oxygen, nitrogen, and carbonic acid, to constitute the atmosphere, and is wafted above the surface of the globe, until local depression of temperature causes its condensation into a liquid, or its congelation into a solid, and its fall as dew and rain, or snow and hail, according to the "times and the seasons."

The annexed table exhibits at one view the respective weights of the elementary gases and compound vapours, which are mechanically blended by the hand of Infinite Wisdom, to constitute one hundred parts by weight of atmospheric air.

Oxygen gas	.	.	.	.	23.32
Nitrogen gas	.	.	.	.	75.55
Carbonic acid vapour	.	.	.	.	0.10
Watery vapour	.	.	.	.	1.03
					100.00

Chemistry demonstrates that no elementary or compound gas or vapour, no mixture or combination of elementary or compound gases or vapours, can be substituted for atmospheric air to support the vital functions of the animated creation.

Accurate analysis educes uncombined oxygen and nitrogen from air, carbon from its carbonic acid vapour, and hydrogen from its watery vapour, and thus establishes the extraordinary fact, that the ultimate elements of "the common air" are oxygen, nitrogen, hydrogen, and carbon.

The science of astronomy proves the terraqueous globe to be enveloped by the atmosphere, which is held around its surface by the miraculous power physically known as the attraction of gravitation, and is thus restrained from dispersion into space by the centrifugal force of the rapid axial and orbital revolutions of the gigantic sphere.

Astronomical observations and calculations regarding celestial phenomena lead to the conclusion, that the atmosphere extends, from the level of the ocean, to an altitude or thickness of forty-five or fifty miles around the globe, the diameter of which is eight thousand miles; or, in other words, the altitude of the atmosphere is nearly equal to the one hundred and sixtieth part of the diameter of the globe. Thus, if a ball twenty inches in diameter be closely invested with a case or envelope one-eighth of an inch in thickness, the arrangement will denote with much accuracy the foregoing relative proportions of the terraqueous globe and the circumambient atmosphere. The assertion may appear incredible, but the fact is indubitable, that the total weight of the atmosphere has been experimentally determined, and it is expressed by the astounding sum of five quadrillion, two hundred and eighty seven trillion, three hundred and fifty billion of tons.

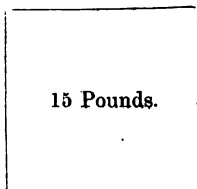
This total weight, which surpasses all comprehension, consists of individual weights of the elementary and compound principles of the atmosphere as here subjoined:—

Elements and compounds.	Weight in tons.
Oxygen gas . . .	1,233,010,020,000,000
Nitrogen gas . . .	3,994,592,925,000,000
Carbonic acid vapour	5,287,305,000,000
Watery vapour . .	54,459,705,000,000
	5,287,350,000,000,000

This result was not obtained by the ordinary method of weighing, but by a contrivance founded on the following fact.

If a tube, thirty inches in length, and one inch square internally, closed at one end, be filled with mercury, the liquid metal will weigh fifteen pounds; if the open end of the tube be then inverted into a cup or cistern containing mercury, the tube will remain full, its mercury being prevented from falling, by the pressure of the external atmosphere upon the surface of that in the cup or cistern.

From this fact it follows, if a column of mercury of thirty



inches altitude, one inch square, and fifteen pounds weight, can be sustained in the tube by the force of the external atmosphere, that it must press with a weight equal to fifteen pounds upon a square inch of surface; thus, by calculating the number of square inches upon the entire superficies of the terraqueous globe, the total weight

of the atmosphere was discovered.

The principal mechanical or physical properties of the atmosphere will be noticed as this inquiry progresses, but one fact concerning the weight or density of a given volume of air, admits of present mention, as it forms the foundation of a most important proceeding in Chemistry and other experimental sciences.

A limited volume of atmospheric air, and of every gas, and vapour, admits of being weighed in a standard balance, and thus many of the foregoing facts have been ascertained, but to gain precision of expression regarding the relative densities of each, they must each be weighed against an equal volume of one particular substance chosen as a standard of unity, and this proceeding will immediately discover if the relative densities of each be above or below that of the standard. A volume of atmospheric air deprived of its

watery vapour, and carbonic acid vapour, by the chemical affinity of lime or other agents hereafter to be mentioned, is chosen as a standard; its inherent weight is considered as equal to 1,000, or unity, when the mercury in the barometer stands at thirty inches, and that in the thermometer at 62°; the one instrument indicating the mean pressure, and the other the mean temperature of the atmosphere.

Volumes of the different gases and vapours now mentioned, all anhydrous with the exception of steam, all at the above pressure and temperature, all equal to the measure of the atmospheric volume, when weighed against it present different numbers indicative of their relative weights, and prove that some are lighter, and others heavier than air. Thus, for example, atmospheric air being 1000, hydrogen is 69, steam 623, nitrogen 976, oxygen 1111, nitric oxide 1041, nitrous oxide 1525, carbonic acid 1525, and chlorine 2470. In the technical language of experimental science, 1000 denotes the specific gravity of atmospheric air, consequently the above numbers denote the specific gravities of the different gases and vapours; all these are more explicitly and usefully denoted by the use of decimals, and the abbreviations sp. gr., or s. g., to avoid tautology.

Thus, atmospheric air sp. gr. 1.000, hydrogen s. g. 0.069, steam s. g. 0.623, nitrogen s. g. 0.976, oxygen s. g. 1.111, nitric oxide s. g. 1.041, nitrous oxide s. g. 1.525, carbonic acid s. g. 1.525, and chlorine s. g. 2.470.

Hence it appears that the specific gravities of hydrogen, steam, and nitrogen, are less than the specific gravity of air, and the specific gravities of nitric oxide, oxygen, nitrous oxide, carbonic acid, and chlorine, are greater than the specific gravity of air; it is also worthy of especial notice for practical purposes and familiar expressions, that hydrogen is about fourteen times and a half lighter than air, whilst carbonic acid is more than once and a half, and chlorine nearly twice and a half heavier than air.

Constant reference will be made to the specific gravities

of the foregoing, and many other substances, that will present themselves during this examination of the chief chemical phenomena of the four seasons, and the importance of such knowledge regarding the relative densities of matter will become manifest in aiding the interpretation of numerous and extraordinary natural changes, which are beneficially ordained to ensue for the welfare of the animated creation. In present conclusion of the subject, it may be stated, that the term specific gravity denotes the weight of a substance, be it either gas, vapour, liquid, or solid, in relation to the weight of an equal volume, measure, bulk, or mass, of one particular substance of any physical form that may be chosen as a standard of unity.

The Almighty, "He looketh to the ends of the earth, and seeth under the whole heaven, to make the weight for the winds, He weigheth out the waters by measure;" He ordaineth the latter to be present throughout the former, as invisible vapour and opaque clouds, causeth it to "distil as the dew," which, "after heat refresheth," and "to pour down rain abundantly according to the vapour thereof," that "the earth shall yield her increase." He congealeth it as "the hoary frost of heaven"—"He maketh the clouds firm, and the hailstones are broken small"—"He casteth forth his ice like morsels, who can stand before his cold?" The Creator has also lavishly poured forth water to give diversity to the beautiful scenery of the globe, as the gushing fountain, the mountain torrent, the placid lake, and the gliding stream, which, swelling to the rapid river, is ultimately received in the bosom of the vast ocean; "He bindeth the floods from overflowing," and causeth them closely to invest the huge terrestrial sphere.

By the Supreme Power, "when the cold north wind bloweth, and the water is congealed into ice, it abideth upon every gathering of water, and clotheth the water as with a breast-plate." He thus sealeth up the hand of every man, that all men may know his work."

In all its physical states, vapour, liquid, and solid, this wonderful compound so familiarly known as water, enacts a vast and important share in sustaining that harmony and order of the creation which is everywhere so conspicuous to a philosophic mind.

Rain from clouds above an open country, even if collected before it touch the earth, is not absolutely pure water, it invariably contains atmospheric air, and compounds of oxygen, nitrogen, and hydrogen; these will be particularly mentioned in the sequel, but it may now be stated that their presence adds materially to the well known fertilizing property of spring and summer showers.

The water of springs, brooks, rivers, and lakes, always contains atmospheric air, and earthy and saline compounds, especially chloride of sodium—common salt—though not sufficient to render it brackish, and unfit for the beverage of man and animals; when these compounds do not exceed a three thousandth part of the weight of the water, it is called “soft,” if they exceed this proportion, it is called “hard”

The water of springs in some localities frequently contains so large an amount of peculiar gaseous, earthy, saline, or metallic compounds, as to be unfit for domestic use, though valuable on account of their specific medicinal virtues; such water is generally known as mineral water. The water of the ocean contains more than three per cent of its weight of compounds, which render it unfit for beverage; as when so used, in cases of dire suffering from want of fresh water, it induces delirium and death; the principal of these compounds is the chloride of sodium; it causes the salinity, whilst the chlorides of magnesium, calcium, potassium, and the combinations of iodine and bromine with these three metals, and sodium, cause the bitterness of sea water.

Iodine is a solid, heavy, compact, moderately hard, friable, of a steel-grey lustre, fusible, and volatile; its vapour has a lovely violet colour; hence the origin of its

name from the Greek *iodes*, signifying *violet coloured* ; it has a pungent odour, irritating and poisonous ; it is slightly soluble in water, and has strong powers of combination with metallic and non-metallic elements ; the resulting compounds when not acid, are termed iodides, thus the iodides of sodium and potassium are present in sea water, in some kinds of mineral water, and also as components of marine plants and zoophytes.

Bromine is a liquid, heavy, and of a dark brown colour, it boils at a moderate heat, and forms a vapour of a dark orange colour, and most offensive odour ; hence the origin of its name from the Greek *bromos*, signifying *a stench* ; it is a deadly acrid poison, insoluble in water ; it congeals into a brittle solid at a low temperature ; it has an extensive and powerful affinity for the metallic and non-metallic elements ; the resulting compounds, when not acid, are termed bromides ; thus the bromides of sodium and potassium are present in sea water, and in some kinds of mineral water.

Magnesium is educed from magnesias, an earthy substance, originally discovered at Magnesia, a province of Asia Minor ; hence the origin of the names magnesias and magnesium ; the former is an oxide of the latter, which is present in sea water, chiefly as a chloride ; the properties of both will be more conveniently detailed in following pages.

Potassium is solid, soft, and malleable at common, brittle at low, temperatures ; its lustre resembles that of silver, it tarnishes in the air, it floats and burns on water, it burns when heated, its flame is of a splendid purple colour, its tarnish and the ash of its combustion are identical in composition, and known as the oxide of the metal, or potash, which is a solid, white, acrid, caustic, soluble and alkaline substance, first discovered in the ash resulting from the combustion of common weeds in iron pots, hence the origin of the term, now modified into that of potassa, for the sake of euphony, and to denote the fact of it being a metallic

oxide, page 9, from whence the metal is educed; both have extensive and important powers of combination; the affinity of the metal for oxygen, surpasses that of all other substances, and it is the lightest solid form of matter.

During all the experimental researches which have been instituted regarding the composition of water from its different natural sources, no instance has been discovered of its occurrence perfectly pure, or solely consistent of oxygen and hydrogen, page 19; it can only be so obtained in very small portions by artificial processes of the utmost exactitude and difficulty, and then it is totally unfit for use as a beverage, both on account of its scanty quantity, and its absolute purity.

This chemical fact calls forth an acknowledgment of the wise and beneficent provision made by the Creator, in ordaining the bountiful supply of water that is naturally presented, and destined for the relief of thirst, to contain certain extraneous matters which are indispensably requisite for exciting and maintaining the healthy and vigorous action of the recondite functions of vitality.

Some of the properties of absolute water have been mentioned, page 19, its other are as follow; when the barometer is at thirty inches, and the thermometer at 62°, one cubic foot of water weighs 1,000 ounces avoirdupois, it boils at 212°, and changes into 1,690 cubic feet of steam, which at any lower temperature will condense and change into one cubic foot of water, this will change into ice at 32°.

When the barometer indicates thirty inches, and the thermometer 62°, the specific gravity of water is equal to 1.000, and it is adopted as a standard of unity, to which the specific gravities of liquids and solids are referred; the principal substances which have been mentioned as occurring in these physical states, present the following results. Liquids:—water 1.000, nitrous oxide 0.830, carbonic acid 0.830, sea water 1.002, brine 1.220, chlorine 1.330, bromine 3.000. Solids:—water 1.000, potassium 0.875, ice 0.940, sodium 0.972, diamond 3.500, iodine 4.946, iron 7.800.

Water is adopted as a test of solubility and insolubility; and whenever a substance is stated as soluble or insoluble, in the one case it is understood to assimilate with the liquid state of water, and in the other to preserve its own specific state.

Knowledge regarding the composition of water is of the utmost importance in experimental science; this fact will become evident as we proceed with the particular examination of the phenomena of the four seasons; but one point in connexion with it may have present mention, as it forms the foundation of a code of laws which govern all chemical combinations and decompositions.

The usual weight of a solid, liquid, gas, or vapour, submitted to analysis is 100, 1,000, 10,000, or other whole number of parts, from whence the proximate or ultimate elements are educed and stated, according to their weight per cent., as in the examples which have been presented, page 15; these, although correct, are fractional, and difficult to remember, therefore means are sought to reduce them into whole numbers, for a more convenient yet equally accordant statement.

By the analysis of 100, 1,000, or 10,000 parts by weight of water, its elements are invariably educed in the following weights:—

Hydrogen	11.1	111	1110
Oxygen	88.9	889	8890
	100.	1000	10000

Hydrogen and oxygen have an extensive range of combination with other elements, and when the compounds so produced are submitted to analysis, all their elements are educed in definite weights.

Hydrogen combines in the smallest definite weight, and this is adopted as a standard of unity, to which the combining weights of all elements and compounds are explicitly referred. To discover the smallest weight of oxygen that is

combined with the smallest or unit weight of hydrogen, the per centage result of the analysis of water is arranged proportionally thus:—

Hydrogen.	Oxygen.	Hydrogen.	Oxygen.
11.1	: 88.9	:: 1	: 8.009

The number 8.009 thus appears as the smallest weight of the oxygen that is combined with the smallest or unit weight of hydrogen; for all practical purposes the minute fraction may be omitted, and the elements considered as combined in the proportions by weight of hydrogen 1+oxygen 8=water 9.

The numbers 1, 8, and 9, denote the smallest weights in which the elements and the compound combine with other elements and compounds, and the numbers to denote the smallest combining weights of these are discovered by a series of comparisons with the foregoing data.

Thousands of experiments have been made upon this important law of definite combination of the smallest weights of elements and compounds in relation to hydrogen as a standard of unity, a few of the results may be stated.

Thus, as regards the elements which are of the most importance to the present investigation, the numbers denoting their smallest combining weights are as follow:—Aluminum 10, bromine 78, calcium 20, carbon 6, chlorine 36, hydrogen 1, iodine 125, iron 28, magnesium 12, nitrogen 14, oxygen 8, phosphorus 32, potassium 40, silicium 8, sodium 24, and sulphur 16.

These numbers indicate not only the smallest weights in which the elements combine with hydrogen and oxygen, but the relative weights in which the elements combine with each other, or in which they are equivalent to each other, or capable of exactly and mutually replacing each other, hence they are called equivalent numbers; which are whole numbers, practically correct, easily remembered, and immediately furnish a clue to the simplest statement of the component weights of primary and secondary combinations,

as in the following examples:—hydrogen 1+oxygen 8=water 9; oxygen 8+iron 28=oxide of iron 36; oxygen 8+calcium 20=oxide of calcium 28; oxygen 8+magnesium 12=oxide of magnesium 20; oxygen 8+sodium 24=oxide of sodium 32; oxygen 8+potassium 40=oxide of potassium 48; chlorine 36+sodium 24=chloride of sodium 60; chlorine 36+calcium 20=chloride of calcium 56; chlorine 36+magnesium 12=chloride of magnesium 48; chlorine 36+potassium 40=chloride of potassium 76; iodine 125+sodium 24=iodide of sodium 149; iodine 125+potassium 40=iodide of potassium 165; bromine 78+sodium 24=bromide of sodium 102; bromine 78+potassium 40=bromide of potassium 118.

Further investigation of the law of definite weight reveals that substances frequently combine in more than their single equivalent weights, and in such cases each succeeding weight is some simple multiple of the single equivalent weight. Thus, oxygen 8+carbon 6=carbonic oxide 14; but oxygen $8 \times 2 = 16$ +carbon 6=carbonic acid 22; and oxygen $8 \times 3 = 24$ +carbon $6 \times 2 = 12$ =oxalic acid 36; so that the weight of oxygen in the second compound is twice, and that in the third compound thrice, greater than that in the first compound; and the weight of the carbon in the third compound is twice greater than that in the first and second compound.

Again, oxygen 8+iron 28=oxide of iron 36; but oxygen $8 \times 3 = 24$ +iron $28 \times 2 = 56$ =an oxide of iron 80, so that the latter contains thrice the weight of oxygen, and twice the weight of iron that the former contains; accordingly the one is called the first, or proto-oxide, and the other the last, or per-oxide of iron.

Carbonic oxide is a gas, invisible, inodorous, poisonous, combustible, its flame has a beautiful blue colour, it has no acid property, and but few powers of combination.

Oxalic acid is a white solid, brittle, intensely acid, and virulently poisonous; it is obtained from the juice of the

plant called the *oxalis acetosella*, hence the origin of its name; it has extensive powers of combination.

Proto-oxide, or protoxide of iron, is the black brittle scoria that incrusts a heated mass of iron; per-oxide, or peroxide of iron is the yellow or red rust that forms on a mass of iron exposed to damp air; the native combination of these oxides constitutes the loadstone.

Many cases are discovered in which one element will retain its single equivalent, whilst that of another, after a first combination with it, will increase in a definite ratio to form other combinations; this important fact may be demonstrated by the five compounds of nitrogen and oxygen :—

1. Nitrogen 14+oxygen 8	=nitrous oxide	22
2. Nitrogen 14+oxygen 16	= 8×2 =nitric oxide	30
3. Nitrogen 14+oxygen 24	= 8×3 =hyponitrous acid	38
4. Nitrogen 14+oxygen 32	= 8×4 =nitrous acid	46
5. Nitrogen 14+oxygen 40	= 8×5 =nitric acid	52

The single equivalent weight of the nitrogen remains in all the compounds of the series, whilst the weight of the oxygen increases by multiples of its single equivalent weight in the first compound; or, in other terms, the second compound contains twice, the third three times, the fourth four, and the fifth five times, the weight of the oxygen that the first compound contains.

The investigation of the specific gravities of gases and vapours attains a great and important extent, when hydrogen is assumed as a standard, the specific gravity of its volume being considered as equal to 1, or unity. Thus, hydrogen being 1, nitrogen is 14, atmospheric air 15, oxygen 16, chlorine 36, carbonic acid 22, nitrous oxide 22; hence it appears that the specific gravity of oxygen is exactly double its equivalent, but the specific gravities of the other substances—atmospheric air excepted, as it is neither an element nor a compound, but a mixture—are exactly those

of their equivalents; this remarkable fact holds good with all substances which are usually considered as capable of assuming the form of gases or vapours, with the exception of sulphur and phosphorus, but their vapours can only be obtained and experimented upon by the most refined operations of Chemistry, and any description of their peculiarities would greatly embarrass the present inquiry; therefore attention is directed to the substances the specific gravities of which have been enumerated.

When these gases or vapours enter into mutual combination they always do so in volumes which bear a simple relation to each other, as one to two, one to three—with the exception of oxygen, the lowest combination of which is a half volume—and although the resulting gaseous or vaporous compounds invariably equal the added weight of their components, they do not invariably equal their added measure or volume, for in many cases the volume of the compound gas or vapour only equals the original volume of one of its components, or in other words, two volumes of the elements contract into one volume of the compound.

For example:—hydrogen 1 volume equal in weight to 1, combines with chlorine 1 volume equal in weight to 36, and produces hydrochloric acid, 2 volumes equal in weight to 37; oxygen 1 volume equal in weight to 16, combines with nitrogen 1 volume equal in weight to 14, and produces nitric oxide 2 volumes equal in weight to 30; nitrogen 1 volume equal in weight to 14, combines with hydrogen 3 volumes equal in weight to 3, and produces ammonia 2 volumes equal in weight to 17; oxygen $\frac{1}{2}$ volume equal in weight to 8, combines with hydrogen 1 volume equal in weight to 1, and produces water vapour 1 volume equal in weight to 9; oxygen $\frac{1}{2}$ volume equal in weight to 8, combines with nitrogen 1 volume equal in weight to 14, and produces nitrous oxide vapour 1 volume equal in weight to 22.

Therefore, as regards hydrochloric acid and nitric oxide, no contraction of volume ensues, whilst as regards ammonia

a contraction of four volumes into two volumes ensues; and as regards water and nitrous oxide, a contraction of one volume and half a volume into one volume ensues. Hence, in reference to hydrogen as unity, the specific gravity of the volume of the vapour of water is 9; and that of nitrous oxide vapour is 22: but the specific gravity of hydrochloric acid vapour is $18\frac{1}{2}$, or the half of the two volumes; and that of nitric oxide gas is 15, or the half of the two volumes; lastly the specific gravity of ammonia vapour is $8\frac{1}{2}$ or the half of the four volumes.

Hydrochloric acid is a vapour, invisible, instantly fatal to animal and vegetable life, soluble in water, the solution is intensely acid, the vapour condenses into the state of a colourless liquid by pressure and cold; its combinations are few, and are named hydrochlorates.

Ammonia is a vapour, invisible, its odour resembles, but far surpasses, the pungency of strongest hartshorn, it produces instant suffocation, it is soluble in water, the solution has the odour of the vapour, and a hot acrid taste; the vapour condenses into the state of a colourless liquid by pressure and cold, the liquid congeals into the state of a white solid at an extremely low degree of cold, and is then inodorous; it is called an alkaline substance on account of its property of combining with, and neutralizing, the virulence of acids; thus, combined with hydrochloric acid it produces hydrochlorate of ammonia, a white and comparatively innoxious solid, originally discovered in the vicinity of the temple of Jupiter Ammon in Africa, and therefore called ammoniac; from it is derived the term ammonia, which is always employed, although as the vapour consists of hydrogen 3 = 3 + nitrogen 1 = 14, its strict chemical appellation to denote the three of hydrogen is that of ter-hydruret of nitrogen.

The vapour of ammonia is occasionally present in the atmosphere, and it neutralizes the nitric acid which is produced during the thunder-storm; the secondary compound thus formed consists of 54 nitric acid + 17 ammonia = 71

nitrate of ammonia ; it is soluble in the waters of the shower, and descends with them to fertilize the land.

Chemistry discovers that sand, clay, lime, and magnesia, which are popularly known as earths, are in fact, definite compounds of oxygen and metals, and accordingly, in strict nomenclature, they are styled metallic oxides, but in this general inquiry it will be more convenient to call them by their popular names.

The metals of the earths, are named silicium, aluminum, calcium, and magnesium, the derivations of the two latter names have been mentioned, those of the two former are from the Latin words *silex*, *flint*, and *alumen*, *clay*.

None of these metals are found native, they are educed by analysis, and are of no practical utility.

Their oxides, and the combinations of these with other substances, which are abundant natural productions, constituting earths and minerals, have important properties.

The oxides of silicium and aluminum are respectively named silica and alumina for the sake of brevity and euphony.

As the metals, calcium and magnesium have been described, the two other metals silicium and aluminum now require brief description.

Silicium is a solid, colour dark brown, insoluble, infusible, combustible when heated ; some chemists deny its metallic nature, and rank it with the non-metallic solid combustible elements, and call it silicon, but it will be regarded as a metal throughout this inquiry. Aluminum is a solid, grey lustre, insoluble, infusible, but combustible when heated red hot. Magnesium is a solid, silvery lustre, hard, malleable, insoluble, infusible, but combustible when heated.

Silica nearly pure, is abundantly found native in the form of white sand, it is hard and gritty, insoluble, under all ordinary conditions ; infusible, excepting in the most intense artificial heat ; it also occurs more or less pure, constituting flints and pebbles ; it may be considered as the most

abundantly diffused of all the earths, being scarcely, if ever, absent from the constitution of any rock, mineral, or soil; its importance to the growth of wheat, barley, oats, rye, grass, cane, rushes, &c., demands the close attention of the agriculturist; its utility in the various arts of glass making, pottery, brick and cement making, is of the greatest interest to all practical men.

A mineral, beautifully transparent and colourless, extremely hard, and having the form of a six-sided prism, with a six-sided pointed summit, was known to the ancients, and imagined by them to consist of water, more densely congealed than in common ice, and therefore incapable of thawing by solar heat, this mineral they named crystal, from the Greek *crystallos*, ice, but Chemistry has demonstrated it to be the oxide of silicium in a state of native purity, its elements being oxygen 8 + silicium 8 = silica 16.



Fig 1.

In the sciences of Chemistry and Mineralogy, the term crystal is employed to denote any natural or artificial solid substance having a geometrical form, however this may differ from the six-sided prism, with a six-sided pointed summit, of the ancient crystal; whilst the term amorphous—void of form—is employed to denote all natural and artificial solids that have not geometrical forms: hence solids are spoken of as being either crystalline or amorphous.

Silica either as a crystalline mineral, or as an amorphous flint, is absolutely insoluble; this fact, and also that of the incorruptibility of water throughout the lapse of ages, being exemplified by the occurrence of crystals and pebbles of silica containing water, which upon analysis, is discovered to contain no traces of the silica in which it was imprisoned.

But it has been discovered that the aggrégation of silica is overcome by some occult process that naturally occurs in subterranean regions, and then it is rendered soluble, as exemplified in those extraordinary springs known as the

boiling fountains, or the Geysers, in the vicinity of the volcanoes of Iceland.

The waters of these fountains gush boiling hot from the earth, to a vast height in the air, and as they fall and evaporate, they deposit a silicious incrustation upon the sides of the natural cavities into which they are received, and upon the surrounding peat, moss, and grass; the leaves of the stunted trees which grow near these fountains are likewise siliciously encrusted, and appear as though carved out of white stone or petrified, yet preserve not merely their general form but their minute fibres uninjured.

Oxygen 8 + aluminum 10 = oxide of aluminum or alumina 18, is a very rare crystalline mineral known as adamantine spar, on account of its hardness being second only to that of the diamond; alumina nearly pure is more commonly known naturally combined with an equivalent of water; it is then a soft white solid, inodorous, tasteless, infusible, insoluble, but miscible with water, and in such state is distinguished from all other substances by its plasticity, tenacity, and adhesiveness; it is the cause of the compactness of what are called stiff-lands or soils, and is esteemed by the potter as the basis of every variety of earthenware and porcelain.

Alumina, thus chemically hydrated, and mechanically mingled with water, does not lose its invaluable property of plasticity when mixed with a considerable amount of the other earths or metallic oxides; thus potter's clay contains much finely divided silica, yet admits of being fashioned into shape for the manufacture of articles of pottery, which are then dried in the air, and subsequently baked in ovens, that the water employed to give plasticity to the clay may be perfectly expelled, and the anhydrous alumina and silica induced to combine and form compact, hard, and insoluble earthenware.

Native white clay, consisting of hydrate of alumina, nearly pure, is distinguished as porcelain clay, and is not

abundant, excepting in districts where a certain variety of granite is prevalent; it is then discovered to result from the slow and spontaneous disintegration of one of the proximate elements of the rock, which proximate element is aluminous, crystalline, and called felspar; its crystals are often prominently seen in many specimens well known to architects, engineers, and builders, as "decomposing granite," and on such account it is unfit for employment in the construction of any works intended for durability when exposed to the naturally combined agencies of air and water.

Native coloured clay, known as common clay, is most abundant; it constitutes entire and extensive districts far removed from such as are now granitic; but the sciences of Chemistry and Geology tend to the conclusion that such clay has resulted from the disintegration of granite and other primeval rocks, that were torn from their foundations and overwhelmed by the waters of the Deluge.

The blue, yellow, brown, or red colour of common clay, is occasionally dependent upon organic matters, but more generally upon the oxides of iron, page 30, that are naturally present, either chemically combined or mechanically mixed, with the actual or pure white hydrate of alumina, of which the chief mass of the clay is constituted; this also contains variable proportions of silica, lime, magnesia, potassa, and phosphoric acid, all of which, as will be hereafter shown, are absolutely necessary for the growth of wheat, and cereal grasses.

Oxygen 8 + calcium 20 = oxide of calcium, calcia, or lime 28, is of very rare natural occurrence, it has only been discovered to a limited extent in certain volcanic districts, where probably it has been produced by the combustion of the metal calcium in some unknown subterranean source of the element oxygen; or educed by subterranean heat from some of its abundant natural compounds; when artificially educed from these by chemical analysis, lime is a soft, white, infusible solid; it has a powerful acrid, caustic

taste, an intense affinity for water, in which it slakes, and is slightly soluble; it forms the basis of mortars and cements, and when spread upon land, it corrodes the organic matters of manures, and renders them soluble, and fit for reception by the rootlets of growing plants.

Oxygen 8 + magnesium 12 = oxide of magnesium, or magnesia 20, has never been found native; its hydrate is a rare mineral, but its other compounds are plentiful; some of them constitute mountain ranges; from these, pure magnesia is educed by chemical analysis; it is a soft, white, impalpable powder, infusible, inodorous, tasteless, insoluble; its uses are limited to the sciences of Chemistry and Medicine; some of its native compounds are employed as building materials, and also as an addition to soils for agricultural purposes.

Some of the earths now enumerated and briefly described, are most abundantly found in combination with acids consisting of the non-metallic combustible elements, carbon, sulphur, and phosphorus, combined with oxygen; as carbon and its acid, namely, the carbonic acid, have been already noticed, page 11, sulphur and phosphorus, and their acids next demand attention, previous to entering upon a description of some of their most important earthy combinations.

Sulphur is abundantly found native in volcanic districts, either as a crystalline, or as an amorphous solid; it is a non-metallic combustible element, brittle, orange, or yellow coloured, inodorous, tasteless, insoluble, infusible, and volatile when heated; its name is said to be derived from the Greek *hals*, salt, and *pyro*, fire; it has extensive and powerful affinity for most of the elements; its direct combinations with metals are called sulphurets; thus the beautiful mineral, called lapis lazuli, consists of the sulphurets of silicium, aluminum, and sodium; the combination of sulphur with oxygen produces two distinct acids, which are constituted and named as follows: sulphur 16 + oxygen 16 = sulphurous

acid 32; sulphur 16 + oxygen 24 = sulphuric acid 40; when these form secondary compounds, such compounds are called sulphites and sulphates, the latter, generally speaking, are of the greatest interest and importance.

Sulphur 16 + hydrogen 1 = sulphuretted hydrogen 17, is an inflammable vapour, having a repulsive odour, highly deleterious, soluble in water, and constitutes the peculiarity of the waters known as sulphureous springs.

Phosphorus is artificially educed from its natural combinations; it is a non-metallic combustible element, solid, soft, colourless, amorphous, inodorous, tasteless, poisonous, insoluble, spontaneously luminous at common temperatures; hence its name from the Greek *phos*, *light*, and *phero*, *to bear*; inflammable at higher temperatures, it burns with the emission of intensely brilliant yellow light, and the production of dense white smoke, which upon cooling becomes a white crystalline solid; this consists of phosphorus 32 + oxygen 40 = phosphoric acid 72; it is the most important compound of phosphorus, and when it unites with secondary compounds, these are called phosphates.

These matters being premised, an examination of the leading characters of the natural combinations of the earths with the acids may be undertaken.

The compounds of lime are numerous, and presented native in most lavish abundance; thus carbonic acid 22 + lime 28 = carbonate of lime, 50, in various degrees of purity, constitutes chalk cliffs, limestone rocks, white and coloured marbles, calcareous soils, the chief earthy matter of shells, corals, and zoophytes, and a portion of that of the bones and teeth of man and animals.

Carbonate of lime also occurs as a beautiful mineral; its crystalline form is an obtuse rhomboid, transparent, colourless, moderately hard, and very brittle, inodorous, tasteless, insoluble, infusible, decomposable by heat; its volatile carbonic acid vapour then escapes, and its fixed solid lime remains, and by the action of heat upon chalk, limestone,

marble, shells and corals, all supplies of lime—popularly quick-lime—are obtained for useful practical purposes.

Carbonate of lime, although insoluble in pure water, is soluble to a considerable extent, if water be impregnated with a large amount of carbonic acid; this is the case from some unknown cause in limestone districts, and as such carbonated calcareous water gushes from the earth, and becomes exposed to the atmosphere, the excess of the carbonic acid volatilizes, whilst the actual carbonate of lime precipitates upon the surrounding soil, or upon substances immersed in the water-course, so that in time these surfaces appear to be changed into stone, or petrified; the waters capable of producing this curious effect, are called petrifying springs.

When carbonated calcareous water penetrates the roof of a limestone cavern, and by slow percolation, parts with its carbonic acid to the confined atmosphere of such locality, the carbonate of lime is deposited in the form of stalactites and stalagmites, some of which are of surpassing beauty.

Sulphuric acid 40 + lime 28 = sulphate of lime 68, is but rarely presented as an amorphous, white, heavy, translucent mineral known in the science of Mineralogy as anhydrite, to distinguish it from the native hydrate—sulphate of lime 68 + water 9—which is most abundant, and of various degrees of purity, constituting white alabaster, crystalline and amorphous gypsum, satin-spar and plaster stone.

All these varieties part with their constituent water at a red-heat and yield anhydrous sulphate of lime; it is a soft white powder, infusible, inodorous, attracts a certain portion of water with intense avidity, evolves heat and solidifies into a moderately hard white mass: hence its importance in the arts as a strong quick-setting plaster either for plain building or decorative purposes.

Sulphate of lime is slightly soluble, and it is the principal cause of the hardness of spring water.

Phosphoric acid 72 + lime $28 \times 3 = 84$ = phosphate of lime

156; therefore, in strict chemical nomenclature, as the compound contains 1 equivalent of phosphoric acid, and 3 equivalents of lime, allusion is made to the quantity of the latter by naming the compound, tri-phosphate of lime, or occasionally sub-phosphate of lime, to convey the idea that there is an excess of the lime, as a base or foundation for the compound; these matters being conventionally understood, the peculiar compound in question is for brevity, and convenience always called the phosphate of lime. It is naturally presented in great abundance as a hard rock, in some particular localities, but in an incalculable quantity as constituting the chief hard or earthy principle of the bones of man and of the higher order of animals; from these it is obtained by the action of heat, which decomposes their actual organic matters and leaves it fixed as a white solid, brittle, infusible, inodorous, tasteless, and well known as bone-ash.

Chemistry discovers that vegetables cannot grow and flourish without phosphoric acid, and that it is naturally present as phosphate of alumina in fertile soils, or that it may be added as phosphate of lime to sterile soils, in order to render them productive.

Phosphate of lime is present in milk, flesh, wheat, barley, oats, rye, and all other usual varieties of wholesome and nutritious food.

Earths and their compounds, saline substances, metallic oxides, and organic matters incorporated together in various proportions either naturally or artificially, form the ingredients of the generality of soils; the heterogeneous nature of which may be understood from the following result obtained by the proximate analysis of 1000 parts by weight of a fertile soil.

Large silicious stones and gravel	-	143
Fine silicious sand	- -	572
Aluminous earth	- - -	75
Carbonate of lime	- - -	47.5

Carbonate of magnesia	-	-	7.5
Sulphate of lime	-	-	5
Oxides of iron	-	-	12.5
Salts of potassium and sodium	-	-	10
Phosphate of lime	-	-	2.5
Organic matter	-	-	72.5
Water	-	-	52.5
			1000

The more particular examination of soils, and the cause of their fertility will be dwelt upon at a future period of this inquiry.

Air, water, earths, and their compounds, are inorganic substances, they neither grow, nor are they reproduced, they have no stated period of perfection, but vegetable and animal productions, are organic bodies which have vital functions and definite stages of germination, growth, maturity, and decay.

Chemistry discovers that all organic bodies admit of analysis, and it might be reasonably anticipated that hundreds of ultimate elements would come forth during such an extensive investigation of the diversified array of the animated kingdoms; but the fact is otherwise; experiment proves that organic bodies principally consist of three or four ultimate elements, namely, carbon, hydrogen, oxygen, and nitrogen which have been already recognized, page 20, as those of the atmosphere. This extraordinary fact presents a magnificent example of the omnipotence of the Creator, in ordaining four such elements to constitute, on the one hand, the vast aerial mantle of the earth, and on the other, the multitudinous organic forms which enrich and adorn its inorganic surface.

Be it remembered that to constitute organic bodies, the three or four ultimate elements are subjected by their Creator to the heaven-born agency of vitality, and that its

recondite powers surpass all comprehension and control by the limited faculties of man.

All inorganic compounds can be analysed, and their respective elements educed in definite weights, the sum of which will exactly equal the original weight of the compound from whence they were elicited; they can then be induced to unite without redundancy or deficiency, and reproduce the original compound; these analytical and synthetical operations can be repeatedly performed, and they will invariably present the same definite results.

All organic bodies can be analysed, and their respective elements educed in definite weights, the sum of which will exactly equal the original weight of the body from whence they were elicited; but they cannot then be induced to unite and re-produce the original body, or to form any substance having the properties of an organic body.

- An insurmountable barrier is thus presented to the synthetical operations of the votary of Chemistry; but in this case, as in every other when recondite matters appear which do not admit of elucidation by his limited acquirements, the immutable laws of the science forbid all presumptuous attempts to rend the veil of mystery that he cannot raise, and command him to bow in humble submission to the divine truth, that "The things which are impossible with man, are possible with God."

By the first, or simplest analysis of vegetable and animal productions, a certain number of curious and important substances are readily eliminated, which are called proximate elements or principles, as for example, gum, starch, sugar, lignin, wax, gluten, gelatin, albumen, fibrin, and fat; the first six of these are of vegetable, and the remaining four of animal origin. Gum, starch, sugar, lignin, wax, and fat, differ materially in their respective properties, yet they agree in consisting of the ultimate elements, carbon, hydrogen, and oxygen. Gluten, gelatin, albumen, and fibrin, also differ materially in their respective properties, yet they agree

in consisting of the ultimate elements, carbon, hydrogen, oxygen, and nitrogen; the weights of the three, or four ultimate elements are only slightly varied to produce the ten proximate principles; the accompanying table exhibits the results obtained by their ultimate analysis: 1, 2, 3, 4, 5, and 7, are of vegetable origin; 6, 8, 9, and 10, are of animal origin.

Proximate Principles.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Parts.
1. Gum . . .	42.106	6.432	51.462	0	100
2. Sugar . . .	47.000	6.000	47.000	0	100
3. Starch . . .	44.44	6.17	49.39	0	100
4. Lignin . . .	50.00	5.56	44.44	0	100
5. Wax . . .	80.31	13.38	6.31	0	100
6. Fat . . .	79.00	11.80	9.20	0	100
7. Gluten . .	55.70	7.80	22.00	14.50	100
8. Albumen . .	53.37	7.10	23.76	15.77	100
9. Fibrin . . .	52.78	6.96	23.48	16.78	100
10. Gelatin . .	50.00	6.41	25.64	17.95	100

The vegetable proximate principles, with the exception of gluten, contain but three ultimate elements; the animal proximate principles, with the exception of fat, contain four ultimate elements; and whilst its composition is closely analogous to that of most vegetable principles, the composition of gluten is closely analogous to that of most animal principles; the important consequences of these facts will become apparent at a future stage of this inquiry.

The generality of the results which are obtained by the

ultimate analysis of proximate organic principles, admit of being stated according to the equivalent numbers of the respective elements, but the formulæ required for reducing the per centages into the equivalents are rather abstruse, and are therefore not detailed here, as they would tend to embarrass this inquiry ; suffice it then to state the curious fact they have revealed, namely, that several, sometimes many, equivalents of each of the ultimate elements are concerned in the composition of each of the proximate organic principles.

Thus, for example, gum contains 12 equivalents of carbon, 11 equivalents of hydrogen, and 11 equivalents of oxygen; gelatin contains 13 equivalents of carbon, 10 equivalents of hydrogen, 5 equivalents of oxygen, and 2 equivalents of nitrogen ; accordingly gum, gelatin, and all other proximate organic principles which admit of being stated in equivalents, are found to have very high numbers; this will be evident from the accompanying table.

Proximate Principles.	Carbon.	Hydrogen	Oxygen.	Nitrogen.	Equivalent.
1. Gum	$6 \times 12 = 72$	$1 \times 11 = 11$	$8 \times 11 = 88$	0	171
2. Sugar	$6 \times 12 = 72$	$1 \times 9 = 9$	$8 \times 9 = 72$	0	153
3. Starch	$6 \times 12 = 72$	$1 \times 10 = 10$	$8 \times 10 = 80$	0	162
4. Lignin	$6 \times 36 = 216$	$1 \times 24 = 24$	$8 \times 24 = 192$	0	432
5. Wax	$6 \times 34 = 204$	$1 \times 34 = 34$	$8 \times 2 = 16$	0	254
6. Gelatin	$6 \times 13 = 78$	$1 \times 10 = 10$	$8 \times 5 = 40$	$14 \times 2 = 28$	156

In the present state of analytical chemistry, the per centages of the ultimate elements which are deduced from proximate organic principles, do not invariably admit of

accurate reduction into equivalents; such is the case as regards fat, gluten, albumen, and fibrin; a few of the leading chemical properties of the foregoing ten proximate principles may be next described.

Gum, is a hard translucent solid, inodorous, tasteless, soluble in cold and hot water, forming a mucilage.

Sugar is a hard, colourless, transparent, crystalline solid, fusible, inodorous; it has a sweet taste, is soluble in cold and hot water, forming a syrup.

Starch, is a moderately hard, opaque, white solid, inodorous, tasteless, insoluble in cold, but soluble in hot water, forming a solution more or less consistent, according to the proportions of starch and water employed.

Lignin, is a soft, white, opaque solid, inodorous, tasteless, insoluble, and may be deemed the most permanent of all vegetable proximate principles.

Wax, is a soft, white, translucent solid, inodorous, tasteless, insoluble and fusible at a moderate heat.

Gluten, newly obtained, is a soft, opaque, greyish white solid, tenacious, elastic, insoluble, and putrefactive; when dried, it is hard, brittle, and permanent, if preserved from the contact of moisture.

Gelatin, is a hard, transparent, brittle solid, inodorous, tasteless, permanent, soluble, especially in hot water; the solution in cooling forms a thick or thin jelly according to the proportions of the materials employed; it is then extremely prone to enter into putrefaction.

Albumen, occurs in the animal body in two distinct states, namely, as a thick glairy liquid in the blood, and as a soft solid in the muscles; both varieties exposed to moderate heat, dry and shrink into hard, brittle masses, resembling gum; but at the heat of boiling water, they both coagulate into soft solids resembling white of egg, and then putrify with rapidity.

Fibrin, recently obtained from the animal body, is a soft, white, opaque, elastic solid, inodorous, insoluble, putrefactive;

when dried, it is hard and brittle, like albumen—of which it may be considered a variety—and permanent, if kept from the access of water.

Fat, is a soft, white, unctuous solid, inodorous, tasteless, insoluble, very fusible, and extremely permanent.

In addition to the ten proximate principles thus selected to present a general view of the ultimate constitution and properties of organic bodies, there are many others which possess distinct and peculiar characters, such, for example, as oils, resins, acids, and alkalies, all these are of the utmost importance in the arts of life, but have not an immediate connexion with the present inquiry, and therefore are not here particularly described.

Thousands of chemical analyses have been made of the foregoing, and all other proximate principles of vegetable and animal matter, and they have been invariably discovered to contain carbon as one of their ultimate elements; many have been discovered that do not contain oxygen, few that do not contain hydrogen, several that do contain nitrogen, and these are especially prone to spontaneous or putrefactive decomposition, if not preserved from the access of liquid water or its vapour, and, lastly, it has been discovered that all organic productions are combustible.

Accurate chemical investigation regarding proximate organic principles, reveals numerous examples of a remarkable phenomenon which rarely occurs during that of inorganic compounds. Generally, not invariably, each inorganic compound contains elements in proportions by weight different to those in which they occur in any other inorganic compound; but as regards organic principles, it is discovered that one of them may contain, not only the same elements, but the same proportions by weight of those elements as another, and yet differ totally from it in properties.

When this strange fact was originally discovered, chemists could scarcely give credence to the results of their experi-

ments, and suspected some error in their analyses, but these upon repetition with all the refinement and accuracy attainable by human skill, invariably corroborated the original results, and have recently laid the foundation of a standard chemical law, which is known as that of isomerism, from the Greek *isos*, *equal*, and *meros*, *part*, signifying equi-proportionality of elements, and the substances which present this phenomenon are known as isomeric substances.

The three ultimate elements, carbon, hydrogen, and oxygen, constitute the two proximate principles, gum and sugar; one equivalent of the latter is combined with two equivalents of water, to constitute pure crystals,—sugar-candy—so it then consists of 12 carbon, 11 hydrogen, and 11 oxygen; gum likewise consists of 12 carbon, 11 hydrogen, and 11 oxygen; thus the two proximate principles, although they differ so widely in properties, agree in containing not only the same ultimate elements, but the same equivalents of such elements, and are accordingly called isomeric substances.

This one example may suffice to elucidate the law of isomerism, and when it is followed out into all its details and bearings, it constitutes a high and intricate department of Chemistry, abounding in experimental facts and many of them admitting of important practical applications.

All these, and thousands of other extraordinary facts concerning the constitution of organized productions have been revealed by Chemistry, and by it alone, for no other science in the circle of human knowledge, has the power of investigating the inherent habitudes and properties of elementary and compound forms of matter.

Chemistry is founded upon experiment, and its results cannot be predicated by the most profound reasoning; no mathesis could discover the chemical fact, that the stubborn and umbrageous form of a majestic oak consists of the element of the hard crystalline diamond, combined with the

invisible gaseous elements of the soft aqueous shower by which its growth was promoted ; or that the deadly nightshade consists of the same elements as nutritious wheat ; or that generous animal food consists of the same elements as some potent poisons.

Carbon, hydrogen, oxygen, and nitrogen, may be regarded as the chief ultimate elements of organic bodies, but rigid analysis discloses the fact, that several of these also contain minute proportions of other ultimate elements, which are not accidentally, but essentially present to confer specific properties upon the organic bodies in which they are discoverable.

Precisely the same as oxygen and nitrogen may be regarded as the chief ultimate elements of the atmosphere, but rigid analysis discloses the fact, that it also contains minute proportions of the ultimate elements, hydrogen and carbon, which are not accidentally, but essentially, present, to confer upon that medium its specific properties, and without which it would be unfit for the support of animal or vegetable life.

Thus, for example, "in wheat-flour, which principally consists of starch and gluten, there is not more than one part in 1,000 of phosphorus, yet, if destitute of phosphorus, it could not contribute to the formation of bone, brain, or nerve, and would therefore fall in the scale of nutritive importance."

"The blood, which principally consists of albumen, fibrin, and hæmatosyn—red colouring matter—only contains about one 2,000th part of iron, yet without that iron it would not be blood."

Indeed, upon rigid analysis of the solids and fluids of the human body, are discoverable not only carbon, hydrogen, oxygen, and nitrogen, but phosphorus, sulphur, chlorine, aluminum, calcium, iron, magnesium, potassium, silicium, and sodium, in various states of combination ; these fourteen ultimate elements have been also shown to exist in the soil

of the earth, and this extraordinary chemical fact is reverentially adduced in humble corroboration of the sacred testimony that "The Lord God formed man of the dust of the ground."

Chemistry investigates the miraculous transmutation of the proximate elements of seeds, from the time they are sown in the ground to that of their production of plants on its surface; it elucidates the action of the vital functions of their roots and leaves upon the earth, the waters, and the air, from whence by the agencies of solar heat and light they are excited to educe and to elaborate inorganic principles which conduce to the growth and maturity of their own organic structures, and enable them to produce flowers and fruits, and each ultimately to "yield seed after its kind."

To this end the vital functions of plants are actively directed, and when it is fulfilled, they either totally cease, and the plants die, or they are temporarily suspended, and remain dormant, until the return of season again excites them into activity, for a second fulfilment of their beneficently destined purpose.

Chemistry demonstrates that the change of plants from vitality to death, and from death to corruption, is attended with beneficial results, and that the elements into which they are resolved, are again ordained by Providence to become active agents in performing a ceaseless round of good throughout the vast creation.

Chemistry investigates the proximate elements of animal bodies, and elucidates to a certain extent the extraordinary manner in which they are elaborated from food to constitute the various fluids and solids of the miraculous living structures; it institutes researches upon the vital functions of animals, which are equally, if not more, recondite than those of vegetables; it proves the phenomenon of respiration to be dependent upon the atmosphere, and to be materially affected or completely arrested, if any alteration take place

in the definite weights of its elementary and compound principles.

The cessation of vitality is the commencement of decomposition, the proximate elements of dead animal bodies are liberated from their normal affinities; they enter into new arrangements, and produce the noisome stench of putrefaction; but this is ordained to be decomposed by living plants, and to be elaborated by them into new forms of utility and beauty.

In reference to the recondite functions of the animated kingdoms, it may be observed, that vegetables elaborate ultimate elements into proximate principles, which are consumed by animals; vegetables decompose water and ammonia, and evolve oxygen; animals produce those compounds, and secrete that element; vegetables absorb heat and electricity; animals evolve those agents, so, in fact, when these perpetual changes are accurately investigated, it appears that the two kingdoms are mutually dependent, their functions being so harmoniously adjusted, that the one elaborates the exuvise of the other into forms again adapted to the support of both.

Ponderable elements and their compounds are influenced in their chemical properties by the imponderable elements, light, heat, and electricity, which can only be recognized by their effects upon such tangible forms of matter.

Light emanates from the sun, permeates the atmosphere, and impinges upon the earth, where it is imperatively requisite for the welfare of the vegetable and animal creation; its presence stimulates their vital functions into vigorous and healthy action, causes them to secrete and elaborate elements specifically adapted for ministering to their growth and perfection, which in its absence would become prolific sources of morbid and fatal changes.

The science of Optics reveals the wonderful fact that colourless solar light admits of separation into seven coloured rays, namely, red, orange, yellow, green, blue,

indigo, and violet, which are magnificently displayed in the stupendous rainbow. "Look upon the rainbow and praise Him that made it; very beautiful it is in the brightness thereof; it compasseth the heavens about with a glorious circle, and the hands of the Most High have bended it."

Optical experiments lead to the conclusion that the "bow in the clouds" is physically caused when solar rays are distorted or refracted by drops of water; for the phenomenon may be thus artificially imitated upon a microscopic scale; generally, however, for the exhibition of the seven colours, the solar rays are refracted by a prism of glass, and hence the seven colours are popularly known as the prismatic colours; these when collected by a glass lens, coalesce into a focus of colourless light.

If solar light were of one colour, all terrestrial objects capable of reflecting it, would appear of such colour, or if incapable of doing so, they would appear black: but the Almighty has beneficently created solar light of seven colours, and ordained terrestrial objects to differ so materially from each other both physically and chemically, that each exerts its specific action upon the chromatic beam; thus one surface will reflect, whilst another will absorb all the colours; a second surface will reflect a single colour, and absorb all other colours; a third surface will reflect a mixture of several colours, and absorb the remaining colours, so that the eye is constantly relieved by the contrast of absolute white and black, and charmed with the gorgeous hues of the primitive colours and their innumerable secondary combinations.

The particular examination of the refraction and reflection of light, belongs to Optics, but its action upon various elements and compounds is closely investigated by Chemistry, many wonderful results are thus discovered, some of which will demand future attention, but it may be now stated that the coloured rays are possessed of different chemical powers; the red, have the highest, and the violet, the lowest tempera-

ture, the former have but little, and in some instances no tendency to promote chemical changes; whilst the latter are powerful excitants of such phenomena.

Light is accompanied by heat on its swift passage from the sun to the earth, and it is the province of Chemistry to examine the effects of this imponderable element upon all ponderable forms of matter; heat of every degree of intensity can be artificially elicited and controlled in the laboratory, but nothing can be discovered regarding its ultimate nature. The universal presence and effects of heat are of the utmost importance throughout the creation; in subjection to the miraculous and beneficent laws of Omnipotence, it is absorbed and retained by the earth to maintain soils of a temperature most congenial to the germination of seeds and the growth and perfection of plants; it is admitted and rendered latent to an enormous amount throughout the bulk of the waters and the volume of the atmosphere; it is the cause of the liquidity of the one and the elasticity of the other.

The presence of heat throughout these solid, liquid, and gaseous constituents of the globe, specially adapts its surface to the existence and well-being of the animal kingdom, for the withdrawal of its ethereal agency would cause an immediate cessation of the vital functions.

Heat, elicited from numerous terrestrial sources, is a powerful and invaluable agent in the laboratories of science and art; it educes brilliant metals from lapideous ores, produces transparent glass from opaque mixtures of earthy and alkaline matters, transmutes liquid water into invisible steam, contributes to the comfort and salubrity of dwellings, to the wholesome preparation of food, and to the success of numerous operations for supplying the necessities and luxuries of life, which may be so readily apprehended as to require no enumeration.

With one remarkable exception—to be particularly examined in its proper season—all solids, liquids, gases, and

vapours, undergo temporary expansion of mass, bulk, and volume, by the influx of heat, whether emanating from a natural or an artificial source. This temporary expansion by heat, is small in the generality of closely compacted solids, great in mobile liquids, and greatest in attenuated gases and vapours; but they all regain their original dimensions of mass, bulk, and volume, when heat is withdrawn. Some substances, especially the metals, and the generality of their ores, have the property of leading or conducting heat throughout their entire mass with facility, so that all parts thereof, however remote they may be from the point first heated, soon acquire elevation of temperature; these are called good conductors of heat.

Other substances, especially the earths and their compounds, have the property of absorbing and retaining heat at the point of their mass to which it is first applied; they have not the power of leading or conducting it throughout with facility, so that the remote portions do not soon acquire elevation of temperature, these are called imperfect conductors of heat.

Lastly, liquids—with the exception of liquid mercury—gases, and vapours have not the property of leading or conducting heat throughout their bulk and volume; they are called non-conductors of heat, but they have the power of absorbing it at its point of contact; the portion so heated expands, diminishes in specific gravity, and accordingly ascends throughout the cold portions, imparting heat to them, and by this power of convection, all parts of the bulk or volume acquire elevation of temperature.

Some solid imperfect conductors, absorb rays of solar and terrestrial heat, and then emit it to the non-conducting air, these are called radiators of heat; other solid good conductors, repel such rays in the direction from whence they emanated, and are called reflectors of heat.

The beneficial results that ensue from the foregoing different habitudes of solids, liquids, gases, and vapours, with

the agency of heat, cannot be too highly appreciated; for example, the transparent atmosphere is so wonderfully constituted, as to allow the rays of the sun to pass throughout its volume without absorbing their heat; but as they impinge upon the opaque solid earth, it absorbs their heat, and consequently becomes materially elevated in temperature.

Then the local volume of the atmosphere, immediately incumbent upon the heated surface of the earth, obtains heat by such contact, expands, and becomes lighter, it therefore ascends, and conveys heat to upper portions: its place is instantly occupied by another and colder volume; this in turn obtains heat from contact with the heated surface of the earth, expands, becomes lighter, ascends, and imparts heat to other upper portions, and so on; by this curious power of convection, or establishment of ascending and descending currents, the entire volume of the atmosphere hovering above a heated surface of the earth, acquires elevation of temperature indirectly from its contact, and not directly by conduction or absorption of heat from the sun; thus winds and breezes of various degrees of force are produced by the continual motion of cold air to supply the place of that which ascends in a heated state.

Transparent water does not become warmed by direct conduction or absorption of solar heat, but by the contact of the warm air that blows over its surface; all these, and other important facts regarding the habitudes of substances with heat, will be fully discussed hereafter: it may, however, be remarked in conclusion, that the science of Chemistry in ascertaining all facts regarding the constitution of earth, water, and air, and the phenomena which they present when subjected to the influence of heat, is enabled to adduce them in powerful evidence of the consummate design, wisdom, and beneficence of Providence.

Thus, if earth, air, and water were perfect conductors of heat, the animated creation could not exist; the sun would

heat the earth intensely throughout its entire mass, as it would a globe of metal ; it would cause the water to vanish, and the air to be a scorching shroud, or, in the more emphatic language of Scripture, "The heaven would be as iron, and the earth as brass."

Electricity is the third imponderable agent ; it is supposed to be universally present with light and heat, and although not generally manifest to the senses, it is invisibly and silently conducting to the harmony and order of the organic and inorganic creation, and it is humbly presumed to be intimately connected with the mysterious functions of vitality.

It is extremely probable that electricity effects great and important changes within the globe, and that by its continuous agency, minerals and ores are either formed or elicited from central sources, and then deposited in the cavities and fissures of concentric strata, as crystalline gems and metallic veins.

Electricity is frequently disturbed from its latent quiescent state, and displayed in terrific grandeur, as vivid lightning amidst the excited clouds ; its flash from them to the firm earth, and flowing waters, is instantaneously seen ; the sudden collapse of the air, disrupted by its ethereal passage, is subsequently heard as crashing thunder

The Almighty is terrible in his great works ; his wisdom is unsearchable in them ; "He directeth the lightning unto the ends of the earth ; after it a voice roareth."

During this astounding manifestation of Omnipotence, man is permitted to withdraw the lightning from the clouds, and direct it to do his bidding ; he discovers—as in the case of heat—that some substances have the property of conducting, others of retarding, yet others, of arresting the subtile element ; or, in other words, that metals are conductors, earth and water imperfect conductors, air, gases, and vapours non-conductors of electricity.

It is discovered that the imponderable agent may be arti-

ficially excited by the mutual friction of solids, liquids, gases, and vapours, and caused to display phenomena identical with those naturally attendant upon the thunder-storm, though upon a small scale in comparison with its vast extent.

Electricity may also be disturbed from its natural equilibrium, by artificial means dependent either upon the influence of heat over metals, or upon their mechanical contact, or upon their chemical change; when so developed it is continuous or current, whereas by friction it is abrupt and intermittent. By suitable conducting media, current electricity may be silently and invisibly directed to become a most powerful agent for breaking the bonds of affinity by which elements are united, and liberating them in their specific states; thus alone were potassa and soda decomposed, and by the additional aid of heat, and ponderable agents, were lime, magnesia, lithia, baryta, strontia, glucina, yttria, zirconia, alumina, and silica likewise reduced from the rank of ultimate elements, page 10, to that of metallic compounds.

Such is a very general introductory statement regarding the objects and tendency of the science of Chemistry, the elements of natural productions, the agents unto which they are subject, and the experimental evidence which they all afford regarding the power and goodness of their Creator.

The principal phenomena of the Four Seasons which admit of interpretation by the aid of Chemistry, are now to be selected and individually examined; they will be found to present much interesting and useful information, admitting of practical application for increasing the advantages, comfort, and benefit of man, and leading him to an acknowledgment of the transcendent might and ever watchful care of the Supreme Being, "Who hath created these things, that bringeth out their host by number; He calleth them all by names by the greatness of His might, for that He is strong in power; not one faileth."

CHAPTER I.

Spring.

How beautiful is the Creation! how full of harmony, order, and proofs of the power and goodness of God!

Abundantly as these are presented throughout the Four Seasons, they are never more obvious than in Spring, when verdure clothes the earth; as the snow of Winter vanishes under the genial influence of solar heat.

All things rise in praise of the Creator, and He beneficently ordains them to be as salutary to our bodies, as they are delightful to our senses.

Our fervent emotions of gratitude are called forth by this wondrous change of season; and if we cultivate an acquaintance with its glad attributes, and humbly endeavour to interpret the unerring laws by which they are governed, we gain a valuable fund of knowledge, eminently calculated to make us, not only wiser, but better, as it will lead us to the highest appreciation of the miraculous workings of Providence.

The germination of seeds, and the growth of plants, present several phenomena which admit of elucidation by Chemistry; these will first engage our attention.

If we examine a seed—and for our general purpose no better can be selected than a garden bean—we find that its external membrane or covering is easily removed, and then the bulk of the seed may be readily divided, in the direction of its length into two distinct portions, called cotyledons; these enclose the germ, or embryo, whose largest part, or that most embedded in the cotyledons, is called the plumula, and its smallest part, or that almost escaping from them, is called the radicle.

The cotyledons are found to be amylaceous, and insipid to the taste, for analysis proves their chief constituent to be the proximate vegetable principle called starch, containing the ultimate elements, carbon, hydrogen, and oxygen, wonderfully combined and elaborated into the form of the seed, and having no tendency to change their arrangement under any ordinary circumstances during the lapse of ages.



Fig. 2.

If we cast a perfect seed of this kind into the earth—no matter in what position—and after a day or two, carefully remove it for examination, we find that it has sustained changes which are not presented by an equal bulk of inorganic matter—a pebble for instance—that has been similarly situated; if we again place it in the earth, and after another day or two remove it, and so on for several days, we find upon each examination, that the changes it presents become more and more remarkable.

At first the seed swells considerably; its external membrane bursts, then an upward and a downward shoot protrude from the cotyledons, the former being an enlargement of the plumula, the latter an enlargement of the radicle; then, in a few days subsequently, the plumula will emerge from the soil whilst the radicle will penetrate much lower

in it than the original position of the seed ; when this is the case, it will be found that the cotyledons have a sweet and mucilaginous taste, for the dormant vital powers of the seed have been awakened to cause the three ultimate elements of the starch to change their original arrangement, and produce sugar and gum.

At this time, numerous vessels will be observed disposed throughout the cotyledons for the purpose of conveying the newly formed sugar and gum as generous nutriment to the infant plant, until it acquire sufficient maturity to procure other support for its welfare from the air and from the earth. When this happens, the saccharine and mucilaginous principles entirely disappear from the cotyledons, they decay, and allow the plant to become entirely dependent upon the leaves which are developed in the plumula, and upon the fibres which are developed in the radicle for its future sustenance.



Fig. 3.

In order to observe all these curious changes, it will be necessary to plant twenty or thirty seeds for examination, as a solitary seed might become so injured by repeated removals as to be incapable of presenting them in succession.

These silent and miraculous phenomena of germination will only ensue under certain conditions ; in the first place, darkness is required, and it is ensured by the opacity of the soil into which the seed is cast ; in the second place, the seed requires a due temperature, which must always exceed 32° , and never exceed 100° of Fahrenheit's thermometric scale ; it also demands a liberal supply of water, either as liquid or vapour ; and lastly, an unlimited access of air.

These agents must be admitted to the seed conjointly ; for example, plant the seed in the earth, allow it the free

access of water and air, it will not germinate if the temperature of the earth be reduced to 32° ; neither will it germinate between such temperature and 100° , though liberally supplied with water, if the access of the air be prevented.

Bury the seed deep in the earth, it will neither germinate nor decay, it will remain dormant and unchanged; but remove it near the surface, so that the porosity of the soil may admit of the just, and naturally conjoined agencies of air, water, and heat, it will quickly start into life, its plumula will emerge above the surface of the soil and become verdant under the influence of solar light.

Knowledge of the above fact enables the chemist to explain why the surface of barren earth, when newly turned or excavated, so frequently becomes covered with luxuriant vegetation; seeds were buried deep in the earth, by natural convulsions in past ages, and thus rendered incapable of undergoing the changes requisite for their germination; but these are immediately excited, when the earth containing the seeds is dug up, and spread abroad to the action of the agents now described.

Common experience teaches that seeds must always be sown at the depth of a few inches in the earth, or they will never put forth shoots above its surface; the chemical reason of this practice is, that they may gain a requisite supply of air, water, and heat, through the pores of the soil.

Loamy and calcareous soils being porous, admit air, water, and heat to seeds, and are generally fertile, whilst clay soils, being compact, oppose the admission of these agents, and are frequently not so productive; indeed they occasionally retain water in such excess, that seeds become rotten and worthless.

It appears by experiment, that the due absorption of water in properly prepared and tilled soils, is the chief cause by which the cotyledons of a seed are enabled to increase in bulk, to put forth both plumula and radicle, and to change their original constituent, starch, into sugar and

gum; but this matter will be fully considered at a more advanced season; let us now inquire how the genial showers of spring are received and retained by soils, to promote the germination of seeds, and the growth of plants that eventually clothe the surface with verdure.

Experiment reveals the existence of a peculiar physical attractive force between liquids and porous solids generally; it is a most important and ever active agent, admitting of illustration by several simple contrivances, which will be found explanatory of the manner in which water is received and retained by soils.

Take a piece of cane, about an inch and a half long, having its ends cut perfectly flat and smooth, hold it perpendicularly, and place a single drop of water on its upper end; the drop will soon vanish, so will another, and



Fig. 4.

another, until the lower end of the cane become wetted, and a drop remain pendent therefrom. The water will not run suddenly through the pores of the cane, which are as fine as hairs, they absorb and retain it in opposition to the attraction of gravitation—which is perpetually soliciting the fall of all substances to the surface of the earth—and this specific

property of the pores of the cane is called capillary attraction, the term being derived from the Latin *capillus*, *hair*, as it is found to be most strongly exerted between liquids and solids when the pores or channels of the latter are as fine as hairs.

This capillary attraction of the fine pores of the cane, will also raise and retain water in opposition to the attraction of gravitation. Take a similar piece of cane, place one end just below the surface of water, and in the course of a few seconds the upper end will become wetted; again denoting capillary attraction to be superior to attraction of gravitation, or the water would not rise above its ordinary

level; still it is mere mechanical attraction, unaccompanied by chemical change; both the cane and the water are of the same composition as they were at the outset of the experiment.

Take another example, bearing even more directly upon the rationale of natural capillary attraction; a heap of sand consists of countless solid grains of insoluble silica, not in absolute contact, but separated by minute interstices, or, in other words, a heap of sand is full of capillary pores, which will absorb and retain water.

To represent upon a magnified scale the grains of sand, a large glass may be filled with common sized marbles; and to denote the water,—the liquid particles of which, philosophers have likewise every reason to believe are not in absolute contact—a small glass may be filled with rape seed, this, when poured amongst the marbles, will fill the interstices as the water will fill those of the sand.

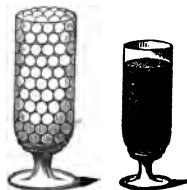


Fig. 5.

Place a shell, or a piece of tile, to cover loosely the small aperture in the lower part of a flower-pot, fill it with dry sand, then pour water upon its surface, and remark the large quantity that may be added before any will flow from the aperture; when it does flow, the capillary pores of the sand are saturated, and being thus incapable of retaining more, the excess passes out in obedience to attraction of gravitation.

When the mould in a flower-pot becomes excessively dry, a large quantity of water may be poured upon its surface before any portion will flow from the lower aperture of the vessel into the saucer in which it is usually placed; this depends upon the capillary attraction of the pores of the mould, which absorb and retain the water until they are saturated, and then they can do so no longer.

Suppose, by continuing to pour water on the surface of the saturated mould, the saucer become filled, the liquid will soon vanish if there be a plant growing with full vigour in the mould; the water, however, does not vanish by drying away,—at least in the common acceptance of the term,—but in consequence of being attracted upwards—as was the water by the porous cane—by the mould in the flower-pot in proportion as the water with which it was saturated is removed by the growing plant, for capillary vessels exist in its roots, these absorb water, and transfer it to the porous stem, leaves, and flowers, from whose surfaces it ultimately dries away or evaporates, and not directly from the saucer. Accordingly, in place of watering the mould, we frequently pour water into the saucer, and depend, as now shown, upon capillary attraction for its rise to maintain the functions of the growing plant.

Some porous substances have the power of raising water to a very considerable extent above its level, as may be proved by a simple, yet instructive experiment.

Select a lump of common salt, cut it with a saw into a regular shape, about six inches long, two inches broad, and one inch thick; then set it before a fire to become perfectly dry. Fill a small shallow plate with water, containing three or four large spoonfuls of red ink, or sufficient to



Fig. 6.

impart a deep tint, and when the lump of salt is perfectly dry, place one end of it in the centre of the water in the plate, that it may stand upright, as here shown.

The lump of common salt, although apparently solid, is in fact, constituted of myriads of small cubical crystals, having interstices between them, or, in

other words, it is full of capillary pores; these will instantly attract the reddened water, and the salt will become power-

fully stained to a very considerable height; the red ink is merely added to render the result more striking than it would be if water alone were used.

In the course of a few minutes the salt will fall; this is on account of the chemical attraction or solvent power of the water undermining its lower part, or in other words, it is on account of the actual solid particles of the salt, being now chemically received by the interstices between the individual atoms of the water; this curious action is regarded as solution, but it does not necessarily follow that a substance capable of exerting capillary attraction for a liquid should be thus soluble in such liquid; a lump of porous sandstone, for instance, similarly placed, will attract water, but will not fall even when fully saturated, because water has no chemical attraction for its particles, or because it is an insoluble substance.

In Nature, it frequently happens that capillary attraction and chemical attraction, or solution, act simultaneously, and produce highly important results in conveying liquid manure containing saline and earthy compounds to the roots of plants, by which their growth is wonderfully promoted.

Capillary attraction is discovered to be an extremely active agent in retaining and administering a proper supply of water to the vegetation upon certain insoluble rocks.

This is very remarkable in districts where the prevailing rocks are either sandstone or limestone, the former abounding in pores, the latter in cracks or fissures; these readily imbibe and forcibly retain the water of showers; we accordingly see large plants, shrubs, nay, even forest trees, flourishing on such rocks, without any perceptible support from mould, but an examination of their positions will discover that the plants, shrubs, and trees, all send forth their roots amidst the pores, cracks, and fissures of the rocks, to gain firm mechanical support from interlacement with them, and simultaneously to derive chemical sustenance from the

water which they retain ; nay, occasionally when these cannot yield a sufficient supply, the roots will actually travel down the external face of the rocks, to seek and attract a due proportion of water from the humid soil at their base.

The case is different when compact granite is the prevailing rock of a district, it is incapable of exerting capillary attraction for water to support vegetation, and therefore stands forth in bare and gaunt outline.

Vegetation on the margin of a river, brook, or pond is generally more luxuriant than on the soil a few yards distant, because the porous earth of the bank attracts water most abundantly, and retains it very forcibly even in time of drought.

Much of the dampness in the walls of buildings depends upon the porous brick or stone work of the foundations attracting water from the humid earth, and it frequently causes great damage and inconvenience.

The building material, which is popularly known as Bath-stone, on account of its abundance in the vicinity of that city, or scientifically known as oolite, on account of its consisting of myriads of small egg-shaped particles of carbonate of lime and silica, loosely conglomerated, is much employed for the decorative architecture of interiors, on account of the extreme facility with which it may be sawed and chiselled into the most delicate and elaborate tracery work, and in such situations, if protected from damp, it will remain unimpaired for ages, a fact that is beautifully exemplified by the monuments and other sculptured work in many ancient abbeys and cathedrals.

Requiring little labour from the masons to produce a magnificent effect, architects have been occasionally induced to employ oolite for exteriors, but in such situations it is not durable, because it quickly absorbs water by capillary attraction, and this extraordinary liquid undergoes expansions and contractions during the changes of atmospheric temperature, and more particularly powerful expansion on

freezing, by which flakes of the stones are violently detached, and the original sharp outline of the work broken down ; this action, silently, yet certainly, continued during successive years, the sculptured work ultimately becomes undistinguishable.

When the careful agriculturist observes a particular district upon which vegetation naturally thrives, it becomes a matter of importance with him to ascertain the cause of such fertility ; and if he apply to the chemist the desired information can be obtained.

He can determine the average quantity of water absorbed and retained by the soil under ordinary vicissitudes of the weather ; can also determine the exact nature of its components, such as the sand, clay, calcareous compounds, and organic matters that it contains, and can if necessary, artificially compose a soil equally fertile with that naturally found, or render the latter still more productive by the judicious and well-timed application of various organic and inorganic matters as manures.

Chemistry thus becomes directly applicable to Agriculture, and many agriculturists have embraced the study of the science ; yet it is by no means necessary for them to become profound chemists, as a good sound practical knowledge of its general outlines if judiciously applied, will be quite sufficient to enable them to ameliorate the condition of soils and crops upon rational principles.

Details regarding the analysis of soils do not admit of introduction here, because they involve the employment of many agents whose action would be unintelligible without a previous and accurate knowledge of the minutiae of practical Chemistry, suffice it to state, that the analysis mainly depends upon presenting to a soil some elementary or compound agent that will attract and remove one of its components in preference to another ; thus, for example, if a soil contained two components, the agent would remove one, and leave the other, so that both could then be individually

recognized; this fact may be illustrated by the following simple experiment.

Mix a heap of iron filings, with an equal heap of sand, let these represent the combined matters of a soil, and suppose their distinct separation to be required, it may be thus effectuated,—thrust a strong magnet into the compound heap, the magnet will only attract and withdraw the iron-filings, the grains of sand will be left, and the analysis immediately performed.

Mix common salt and sand; it would be impossible to separate these by a magnet, as it has no attraction for either of them; it would be difficult to separate them perfectly by picking out their individual grains, even aided by a fine-forceps and a powerful magnifier, therefore as such mechanical means fail in effecting the desired analysis, chemical means must be tried.

Experience teaches that water will dissolve salt, and that it will not dissolve sand, this simple fact affords a clue to the method of effecting their separation; agitate the mixture with water, then allow it to rest, the sand will rapidly subside or precipitate to the bottom of the glass in which the experiment is performed, and leave the water perfectly clear, yet containing the whole of the salt in chemical solution; decant this carefully from the sand, into a shallow basin, place it in a warm oven that the chemical agency of heat may dry away or vaporize the water, and then the solid salt will remain.

This analysis depends upon mechanical and chemical principles; the precipitation or fall of the sand is mechanical in obedience to gravitation, because its specific gravity is greater than that of water, and because it has no chemical attraction for water, or is insoluble; the disappearance of the salt is dependent upon its chemical attraction for water, therefore its solution ensues, and this power so completely opposes that of gravitation as to prevent the precipitation of the salt, even by the most prolonged repose; then, the che-

mical agency of heat changes the water of the solution from a liquid state to a vaporous state, in which it escapes as steam, but having no such power over the actual salt, it remains fixed in its original solid state.

Take a third example, mix equal heaps of salt, sand, and sawdust, suppose them to represent three distinct components of a soil, and that their separation be required; it may be effected as follows:—agitate with water, then allow it to rest, the sand will precipitate, the salt will dissolve, and the sawdust will float; then decant the solution into a fine sieve, the sawdust will remain on its meshes, the solution will filter through, and when heated as directed will yield the solid salt.

This analysis like the former, is dependent upon mechanical and chemical principles; the sand sinks for the reason already given, the sawdust floats because its specific gravity is less than that of water, and has no chemical attraction for water, and may be separated therefrom mechanically, by the intervention of meshes having smaller diameters than its particles, these meshes however, cannot mechanically separate or strain the salt from its chemical solution: this accordingly passes through as brine, from which the chemical agency of heat separates the salt by vaporising the water.

The chemist, by extensive and laboriously acquired knowledge of the habitudes of elementary and compound substances with water and other solvents, is enabled to separate the components of soils; he of course adapts the agents according to the peculiar circumstances of each case, but invariably takes care to educe, or to draw forth, the several components as they naturally exist in the soil upon which he experiments, and not to produce other compounds from them by disturbing or modifying their original arrangements, there being a marked distinction between educts and products, although they are often unintentionally confounded by unpractised operators.

In illustration of the varied composition of soils, fitted for the support of different kinds of vegetables, three analyses are presented in the following tabular statement.

Substances.	I.	II.	III.
Silica	904	728	540
Alumina	13	110	280
Carbonate of Lime	70	112	90
Oxides of Iron .	3	4	50
Organic Matter .	10	46	40
	1000	1000	1000

I. Is a light soil, admitting of ready penetration by the fine fibres of bulbous and tap roots, and therefore well adapted for the growth of turnips, carrots, and beet.

II. Is a compact soil, yet readily penetrable by short radicle fibres, and therefore well adapted for the growth of wheat, barley, and oats.

III. Is a more compact soil, but penetrable by strong radicle fibres, and therefore well adapted for the growth of oaks, elms, and beeches.

The chief portion of the silica, which is a predominant component of the three soils, exists in the form of small pebbles, coarse and fine sand, the remainder as finely comminuted dust; the other components are in a state of fine division, and by the aid of moisture they act as a cement, by which the sand is bound together with compactness proportionate to the quantity of alumina that is present.

The manner in which water is attracted by soils is of great importance to the nutriment of vegetables. If the mechanical and chemical nature of the components of soils be such as to attract water with extreme power, the roots of vegetables will be unable to withdraw it from them, and will accordingly languish; and if the components of soils be such as to attract water abundantly, yet to hold it loosely, it will tend to injure or destroy the fibres of the roots.

The power of soils to absorb water by capillary attraction, depends principally upon the state of division in which their components exist; the more divided they are, the greater their capillary power; thus fine sand will absorb and retain more water than coarse sand; but it must be borne in mind that each component has its own specific degree of capillary attraction.

Thus vegetable matters seem to be more absorbent than animal matters, when employed as manures, and animal matters are more so than compounds of alumina and silica; and these again are more absorbent than carbonate of lime and magnesia; but these differences may depend to some extent upon the relative minuteness of their division, and upon the amount of the surface exposed.

The nourishment of vegetables appears to consist of water, and the decomposing organic matters existent in soils; the earthy components are of utility in retaining water, and also in keeping the organic manure in a proper state of distribution, so that it may not decompose more abundantly or more rapidly in one portion than in another, and that the soluble matters into which it changes may be uniformly absorbed and retained for abstraction by the roots of vegetables to support their growth.

Although many kinds of seed may be sown in a heap of insoluble sand, or even of small lead shot, kept moistened with water, and placed in a due temperature with access of air, and they will germinate and grow; experience teaches that they will do so more perfectly, if some form of

organic matter in a decomposing state, be applied at the same time. Chemical analysis points out the reason of this popular fact; and when we arrive at the consideration of a plant in an advanced stage of its growth, the theory of the action of organic and inorganic manures and other more subtle agents will be elucidated.

We are chiefly indebted for our supplies of spring water to the capillary attraction of the pores and fissures of the earth; these absorb and retain a great portion of rain water, for the maintenance of vegetation, whilst the excess not so employed, percolates or filters downwards, dissolving various proportions of saline and earthy compounds from the subsoil, until it meet with an impermeable stratum of rock or clay, and there accumulates, then seeks capillary outlets from its confinement, and ultimately gushes forth at a distant and lower level as spring water.

Water is known to descend from the atmosphere in the form of rain, and its influence in promoting germination and growth in the spring season has passed into the proverb that "April showers bring forth May flowers."

Experiment proves that such accumulation of water in the atmosphere is dependent upon a beautiful natural phenomenon called evaporation; the term denotes a property possessed by the atmosphere, of causing the surface of water to waste away or to disappear gradually in the state of vapour.

Such evaporation is always proportionate to the temperature of the atmosphere, the rapidity of its movement, and the extent of the surface of the water exposed to its influence.

Fill a broad shallow vessel with rain-water collected before it touch the earth; leave it uncovered and exposed to the air, in a situation sheltered from rain for a few days during warm weather, the whole of the water will ultimately vanish, and leave the vessel perfectly dry.

The rationale of this simple experiment may be thus stated:—air contains a store of latent heat, which incites

the liquid water to change into vapour or steam; this immediately blends with a portion of air, and is wafted away; a fresh portion of air then blows over the surface of the water, and incites the formation and removal of another portion of it as vapour, and so on, until at length the whole of the water is thus changed in its physical or mechanical state.

Evaporation is constantly proceeding throughout Nature from the surface of the waters. The parent source of all fresh water is the vast ocean, although this may not be directly apprehended, as sea water is bitter and poisonous; but an experiment will elucidate this point.

Collect half a pint of rain-water before it touch the earth, select two finger-glasses of equal size, measure a quarter of a pint of the water into each, and in one of these portions dissolve half an ounce of common salt.

Place both glasses in a situation sheltered from rain, but exposed to the air, and in the course of a few days of warm weather the water will have evaporated from both, and will have left no solid deposit in the one, but the original half ounce of common salt in the other.

Absolutely pure water, solely consistent of the elements oxygen and hydrogen,—and rain-water, although not absolutely, is very pure,—is totally volatile by natural or artificial heat; but common salt, and other saline and earthy compounds, which such water is capable of holding in solution, are not similarly volatile, or in other words they are fixed, and accordingly remain as a solid residue when the water has escaped in the state of attenuated vapour.

The saline matters of sea water are fixed at all natural ranges of temperature; and accordingly when currents of air or winds blow over the wide expanse of ocean, their latent heat incites the surface portion of the actual water in which the saline matters are dissolved, to change from the liquid state to that of vapour, and thus to rise and mingle with the atmosphere, to travel "on the wings of the wind"

far inland, where, meeting with depression of temperature, the vapour chills or condenses into drops which the air cannot support, and therefore they fall from it as showers of rain, in obedience to the attraction of gravitation.

These showers partly sustain the vegetable productions of the earth, and partly percolate and accumulate beneath its surface to form springs; these gush forth and meander as streams, and gradually spread and flow onward as rivers, which ultimately fall into their parent ocean, from whence by evaporation, the water again travels inland, again condenses as rain, accumulates as springs, streams, and rivers, and is again received by the ocean, to perform an incessant round of utility, and to display the power and goodness of God.

A similar process is constantly proceeding from the surface of streams, rivers, lakes, and from the humid earth itself. The beneficial effects of this grand natural phenomenon are powerfully set forth in the Sacred writings.

"God maketh small the drops of water; they pour down rain according to the vapour thereof, which the clouds do drop and distil upon man abundantly; and the tree of the field shall yield her fruit, and the earth shall yield her increase."

Again.—"Thou visitest the earth, and waterest it. Thou greatly enrichest it with the river of good which is full of water: thou preparest them corn when thou hast so provided for it: thou waterest the ridges thereof abundantly: thou makest it soft with showers; thou blessest the springing thereof."

How eloquent, how beautiful are the foregoing passages! how calculated to enlighten, adorn, exalt, and purify the mind of a philosophic experimenter, and lead him to extol with reverence and gratitude, the Author and Giver of every good and perfect gift!

The watery vapour present throughout the atmosphere is attracted and imbibed by soils with various degrees of

energy, and is as much connected with their fertility as their direct absorption of water from the showers of spring; indeed when the power of attracting aqueous vapour is great, vegetables are thus supplied with water when no showers fall, and the effect of evaporation from the soil during the day is fully counteracted by its absorption of aqueous vapour during the night.

Porous soils are most active in thus absorbing aqueous vapour; compact soils which absorb a great quantity of water from showers do not, generally speaking, attract much aërial moisture in the absence of rain; they become hard, and the vegetation upon them is liable to wither away.

Chemical analysis of soils distinguished for their powers of attracting aërial moisture, points out that they contain sand, finely divided clay, carbonate of lime, and organic manure, all so lightly bound together as to admit of the perfect access of air to a considerable depth; and the great utility of carbonate of lime and manure, consists in their conferring attractive powers upon soils without rendering them adhesive and compact; sand likewise will destroy tenacity, but it appears to impair these attractive powers.

Soils which attract aërial moisture with the greatest avidity are always the most fertile; the absorptive power of a soil in this respect may be determined by very simple proceedings. Collect the soil in dry weather; then accurately weigh 1,000 grains, which place upon a metallic hot water-plate, filled with boiling water in the usual manner; let the soil be spread out thinly, and constantly stirred about with an iron spoon or steel knife, until no steam condense upon the lower side of a cold dry glass plate, held about an inch above its surface; this is a test that the soil is dry.

Upon carefully removing the whole of the dried soil from the hot plate to the scale pan, it will not weigh so much as

it did, and the number of grain weights required to restore the original balance, will indicate the weight of the water that was retained in the soil by capillary attraction—although it might have felt perfectly dry—and which has been expelled in vapour by the heat; and if the dried soil be left in the scale pan exposed to the air, it will gradually increase in weight by attracting aqueous vapour therefrom.

If it be required to ascertain the utmost quantity of moisture that the artificially dried soil is capable of absorbing

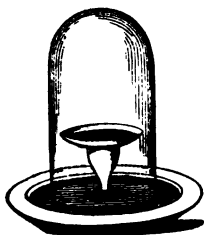


Fig. 7.

from air replete with aqueous vapour, the following arrangement may be made:—Place 1,000 grains of the dried soil in a saucer, supported on an egg-cup in the centre of a dinner plate, full of water, then place a bell-glass, or an earthenware jar inverted over this arrangement, that the rim of the bell-glass, or that of the jar, may stand in the water contained in the plate.

No liquid water can rise to the soil in the saucer; but the vessel with which it is covered contains air, and this air contains heat, which will excite a portion of the surface of the water to rise in vapour, and to saturate the air, or cause it to attain a maximum state of humidity: part of this aqueous vapour will be attracted and condensed by the dried soil, until it be likewise saturated.

Examine the weight of the soil after a few hours, and it will be found to have increased materially; again expose it to the humid atmosphere for several hours, and weigh it a second time: and so on, until upon the last examination it manifest no further increase of weight, it may then be considered to have attracted the greatest amount of aqueous vapour of which it is capable; lastly, place the soil upon the hot water plate, it will become dry and resume its original weight.

One thousand parts of different soils, dried at 212° , and then exposed for one hour to air saturated with aqueous vapour, at 62° , presented the chemist who first devoted his attention to agriculture, with the following results:—

A celebrated soil from Ormiston in East Lothian, which contained more than half its weight of finely divided matter, consisting of 11 parts of carbonate of lime, and 9 parts vegetable matter, gained 18 grains; a very fertile soil from the banks of the river Parret in Somersetshire, gained 16 grains; a soil from Mersea in Essex, worth forty-five shillings an acre, gained 13 grains; a fine sand from Essex, worth twenty-five shillings an acre, gained 11 grains; a coarse sand worth fifteen shillings an acre, gained 8 grains; and the soil of Bagshot-heath gained only 3 grains.

A considerable degree of chemical attraction is discovered to exist not only between water and the alumina of soils, but between the alumina and the organic matter of manure; the latter is thus prevented from decomposing too rapidly and becoming useless, and also from being washed away by the water of showers; or in other words, the combination between the alumina and the organic matter, maintains the soil in a proper state of richness, and capable of affording a judicious supply of nutriment to vegetation, whilst on the other hand, extremely silicious soils have little or no such chemical attraction for organic matter, and therefore often remain poor and incapable of yielding generous support to their produce.

“When soils are immediately situated upon a stratum of rock or stone, they become dry much sooner than when the sub-stratum is of marl or clay, which are strongly absorbent of water, and, accordingly, in some cases, this is of great advantage to light sandy soils as a reservoir of moisture upon which they can draw in time of drought for the support of their vegetation; in other cases where the external soils are too absorbent, this property is corrected by the sub-

stratum being of sand or gravel, this admits of the percolation of the excess of water."

In limestone districts the actual soil is a kind of marl, generally only a few inches deep, but highly absorbent, and capable of supporting vegetation, because the limestone rock upon which it rests, does not allow the water to escape by rapid capillary attraction, whilst, on the other hand, in sandstone districts where the silicious sandy soil, although absorbent, rests on absorbent sandstone rock, vegetation frequently suffers from the capillary attraction of the latter withdrawing the water too rapidly; indeed, during the height of summer, it is not uncommon to see the grass on such sandstone districts parched and browned, whilst that on limestone districts is luxuriant and green.

The enormous amount of fifty-four trillion, four hundred and fifty-nine billion, seven hundred and five million of tons of watery vapour, page 21, is sustained by the atmosphere, which is a mixture of the elements oxygen and nitrogen and the compound carbonic acid, and during all the wondrous changes of the Four Seasons, the atmosphere is never sensibly altered in the due proportion of these constituents.

Even when replete with solar heat, gained indirectly by convection from the warm surface of the earth, the air is simply expanded in volume, and when, from local causes, it has parted with a certain degree of heat, or has cooled, it is simply contracted in volume, and not altered in actual constitution; the action of artificial elevation and depression of temperature upon air, likewise causes the mere expansion and contraction of its volume; a fact admitting of illustration by very simple experiments.

Take a Florence-flask, cleanse its interior and exterior from adhering oil by a strong hot solution of pearlash, wash it thoroughly with rain-water, set it to drain, then wipe its exterior perfectly dry, hold it in front of a fire with its mouth downwards, turn it in the hand that its bulb may

become very hot, to convert the few drops of water that it contains into steam; then remove the flask from the fire, place it on a folded flannel, thrust the nozzle of a pair of bellows within its neck, and blow out the steam; thus the flask will be perfectly dried, let it remain on the flannel to become quite cold; then select a sound soft cork that will accurately fit its mouth—hold the flask by its neck, and not by its bulb, whilst fitting the cork, lest the bulb smash by the pressure, and its fragments wound the hands—lastly, remove the cork and set it aside.

Place the flask with its open mouth to dip beneath the water contained in a finger-glass, as here shown; the flask, although empty, in the ordinary acceptance of the term, is actually full of air; this has no tendency to escape, because it is nearly of the same density and elasticity as the external atmosphere; neither has the water a tendency to enter but a very little way into the neck of the flask, because it is opposed by the included portion of air.



Fig. 8.

Apply the flame of a spirit-lamp very gently to the bulb of the flask, its thin glass will immediately conduct heat through to the air, this will expand in volume, or become too large for the flask to contain, and accordingly a portion will escape from its mouth, and bubble to the surface of the water in the finger-glass. Permit twenty or thirty bubbles of air to escape, then remove the lamp, and as the flask becomes cool, water from the glass will gradually rise into its neck and at last become stationary. These phenomena admit of the



Fig. 9.



Fig. 10.

following simple explanation :—the air expanded by heat, and contracted upon its withdrawal; if the neck of the flask had not been under water, the external air would have entered and restored the original volume; but being under water, the pressure of the external air forced water into the neck, to supply the place of the portion of air which escaped from thence in bubbles during the expansion.

Again apply the flame of the lamp to the bulb of the flask, until the expansion of the portion of air that it now contains, force down the water nearly to the mouth; then remove the lamp, and as the flask cools, the water will rise as before; again heat, and again cool, to the same degree; the air will invariably expand in the one case and contract in the other, and cause the fall and rise of the water, as many times as may be thought proper; the same results will likewise ensue, but with more slowness, upon alternate exposure of the flask to sunshine and shade. When the air



Fig. 11.

has been permitted to contract for the last time, lift the flask with one hand that its mouth may be only an inch beneath the surface of the water; take the cork between the fingers of the other hand, and dip it beneath the water close to the mouth of the flask, so that it may readily be thrust therein; the flask thus corked in an inverted position, is then to be lifted away and placed in its upright position upon a wooden or pasteboard ring; the water that was in the neck of the flask will now occupy part of its bulb, the air will occupy the remainder and the whole of the neck.

Provide a straight piece of slender bell-wire, rather ex-

ceeding the height of the flask, hold the wire perpendicularly, then bend about an inch of its lower end upwards and parallel with, but a quarter of an inch from, the longer portion, and upon the end of this short bend, press that of a bit of small wax taper, about an inch long, that it may be firmly fixed, the other end of the wire may then be turned into a small loop that it may be conveniently held during the following experiments.  Fig. 12.

Kindle the wick of the taper, remove the cork, and gently let the taper down the neck into the bulb of the flask, the flame will there continue for a time with the same brilliancy as in the open air; at last, however, it will cease.

These experiments are to prove that the action of heat, from the flame of the spirit-lamp, conducted through the thin glass of the flask, is to cause mechanical expansion, and that of the withdrawal of heat is to cause mechanical contraction of its included volume of air, and not to cause any chemical change in the relative proportions or properties of its constituents, otherwise the flame of the taper could not continue for a moment when plunged into the air after being subjected to these ordeals.  Fig. 13.

Be the air hot or cold, it invariably contains the relative weights of nitrogen and oxygen which have been so frequently named; the latter element supports the flame of the taper for a time, but it does not continue to burn with the same freedom as in the external air, because actual combustion in a volume of air, deranges the mixture of its constituents, and instantly summons chemical changes into play, which are of most curious and interesting characters.

The chief elements of the wax taper are hydrogen, and carbon; at an elevated temperature these exert chemical

attraction or affinity for oxygen, and combine with it to produce, in the one instance, water, and in the other, carbonic acid; the flame and chemical changes cease, when the definite weight of oxygen is abstracted and combined with the hydrogen and carbon, because the water and carbonic acid produced, and the nitrogen educed by their combustion, can yield it no support.

The flame of the spirit-lamp, when employed for heating the flask, drew upon the external air for its support, and in every case during the combustion of ordinary fuel, which, in common with alcohol or spirit of wine, contains hydrogen and carbon, the air is similarly drawn upon or unmixed, the elements of the fuel combining with the oxygen of the air to produce water and carbonic acid, and liberating the nitrogen for which they have no affinity during combustion. Animal respiration effects changes upon atmospheric air closely analogous to those effected by combustion, air that has passed from the lungs is perfectly unfit for the maintenance of life, or the support of flame; this fact as regards flame, may be experimentally proved by the employment of an apparatus to be next described.



Fig. 14.

Provide a glass vessel in the form of a quart bottle having the lower part removed, the neck fitted with a ground glass stopper; remove this, then place the glass to stand in a shallow pan of glass or earthenware, containing about three pints of water; introduce the lighted taper through the neck of the glass, and ascertain that the included air will support flame; then remove the taper, lift the glass completely from the water, and move it to and fro in the open air, that the pro-

ducts of the flame may escape, and the glass become full of fresh air, it is then to be placed in the water as at first directed.

Make a deep expiration, or sigh of air, from the lungs, quickly apply the lips closely around the neck of the glass, and draw air from it into the lungs, water will rise from the pan into the glass; and when it nearly reach the lips, expel air from the lungs; the water will then fall from the glass to its original level in the pan; again inhale, and again exhale; lastly, remove the lips from the neck of the glass, and immediately insert its glass stopper.



Fig. 15.

The action of the water is merely mechanical, it serves as a liquid piston to rise and supply the place of the air when inhaled, and to fall and yield it place when exhaled; it has no chemical action during the experiment, which might be performed, though not so satisfactorily, by inhaling and exhaling air from and into a bladder.

Kindle the taper, remove the stopper, and introduce the flame through the neck into the glass; the flame will be extinguished as effectually as though it were plunged into water; thus proving that the air must have sustained some most extraordinary chemical change during its brief contact with the lungs.

Chemistry discovers that carbon, is never absent from the constitution of organic matter, and that it is present as an element of the blood, in some peculiar physical state, having a most intense and powerful affinity for oxygen; accordingly when the blood is exposed to the action of the air inhaled by the lungs, carbonic acid is instantaneously produced, whilst nitrogen is educed, the compound and the element are found in the exhaled air, and being mephitic, are unfit

for the further maintenance of life, or for the support of flame.

The manner in which these mephitic results of respiration are prevented from injuring vitality, will present another wonderful example of the wisdom and beneficence of the Creator.

The temperature of the living body is about 98° , and exceeds that of the surrounding air, therefore nitrogen and carbonic acid are exhaled from the lungs in a heated state; the action of vital heat is not merely to expand the exhaled matters, but to render the nitrogen still lighter than it is inherently, and to render the carbonic acid which is inherently heavy, equally light with it, and in consequence of this diminution of their specific gravities, so much below the specific gravity of the air, they quickly ascend through one portion of it from the respiratory organs, whilst another portion of it immediately descends and supplies their place in the lungs, to discharge its functions, and in its turn to undergo a similar change and escape.

This fact admits of experimental illustration by a very simple arrangement: provide a cylindrical glass about eighteen inches long, and four inches in diameter, closed at one end, and its rim ground smooth; also a piece of flat plate glass to cover this; and about a pint of lime-water, which is prepared by adding an ounce of quick-lime to a quart of water, contained in a glass bottle, corking it closely, shaking it several times, then allowing it to settle, and lastly, decanting a part of the transparent and colourless liquid into a clean glass bottle that must be provided with a ground glass stopper.

These preparations being made, place the glass cylinder upright, hold its rim just beneath the under lip, and breathe across its mouth twice or thrice; then cover the mouth of the cylinder with the glass plate, and place it to stand upon a table.

Remove the stopper of the bottle containing the lime-water, next slide the glass plate a little on one side, that sufficient room may be made for pouring about half the lime-water into the cylinder; it is then to be closed with the glass plate, and shaken two or three times for the lime-water to come into contact with the air that it contains; no change will be perceptible in the clearness of the lime-water, it may then be poured from the cylinder into a large tumbler. Hold the cylinder in an inverted position, with its rim just above the upper lip, and breathe beneath its mouth twice or thrice; then cover the mouth of the cylinder with the glass plate, and place it to stand upon a table as before; then proceed as before, and pour in the lime-water from the tumbler, and upon shaking it about, it will lose its transparency, and become milk white.

The explanation, or the rationale, of these experiments may be thus stated:—lime is slightly soluble in water, and then it has a strong chemical affinity for carbonic acid, with which it forms insoluble carbonate of lime: this it will do in time with the minute proportion of carbonic acid that is naturally present in the atmosphere, as may be proved by leaving a tumbler full of lime-water exposed for an hour or more, its surface will become covered with a white insoluble film of carbonate of lime, and so certain is this affinity that lime-water is employed as a detector or test of the presence of carbonic acid.

In the first experiment, the aëriform matters were exhaled from the lungs in a heated state, and therefore they did not fall through the air contained in the glass cylinder held with its mouth upwards, they ascended from the lips and were lost in the air; had they descended, the lime-water would have detected the fact, by the immediate formation of carbonate of lime with the carbonic acid.

In the second experiment, when the glass cylinder was held with its mouth downwards, the heated exhalation from the lungs ascended, and displaced the air that it originally

contained, the lime-water detected this fact, by the immediate formation of carbonate of lime with the carbonic acid.

Thus do the results of respiration, in company with heated aqueous vapour derived from the humid surface of the lungs, ascend and diffuse themselves throughout the vast atmosphere; thus also do the results of combustion, namely, hot vapour of water and of carbonic acid, undergo similar removal from burning fuel, but the results of both phenomena are yet destined to perform a ceaseless round of beneficial changes, the consideration of which will demand future attention, for nothing is rendered worthless in the perfect workings of the Almighty.

The germination of seeds effects chemical changes upon the air, analogous to those just described, and also admitting of experimental verification.

Place a handful of peas in a quart bottle, moisten them with water; introduce a lighted taper for a moment, to prove by its flame continuing, that the air is unvitiated, then close the mouth of the bottle with a sound soft cork, place it in a warm situation, and in a few days germination of the peas will ensue, producing carbonic acid and educing nitrogen, so that upon removing the cork and introducing the lighted taper, its flame will be extinguished.

From experiments similar in principle to the foregoing, but conducted with the utmost skill and precision, the chemist is led to conclude that combustion, respiration, and germination, are active in producing changes upon the nature of the air, and yet he fails to detect in it any undue accumulation of mephitic matters; this is partly on account of the very insignificant volume of air—only a few gallons—which he can confine in his apparatus, and operate upon with analytical agents, but chiefly on account of a discovery that he makes regarding vegetation, which in full vigour, and especially when under the direct influence of solar light, has the miraculous property of decomposing any excess of carbonic acid and educing its oxygen, and of thus pre-

serving the just balance of the atmosphere; this will demand future consideration.

It may now be remarked, that the presence of uncombined oxygen is requisite for the phenomenon of germination to proceed; this condition is wonderfully fulfilled by the atmosphere, in which oxygen is only mechanically blended, and not chemically combined with nitrogen.

The presence of uncombined oxygen is indispensable; that it may exert affinity for a portion of the carbon of seeds, and with it produce carbonic acid, and unless seeds thus part with carbon they will not germinate.

If seeds be placed in nitrogen, or in carbonic acid, supplied with water, and kept at a due temperature, they will not germinate, they will rot, because nitrogen has no affinity for carbon under these circumstances, and carbonic acid can have none, as it already inherently contains that element.

On the other hand, if seeds be placed in oxygen, supplied with water, and kept at a due temperature, they will germinate rapidly, but the action is morbid, for their carbon is unduly abstracted from them by the intense affinity of the oxygen to form an unnatural excess of carbonic acid; so likewise when an animal is imprisoned in oxygen, respiration becomes dangerously hurried by the unnatural escape of carbon from the blood, and death quickly ensues from the extraordinary excitement and derangement of functions into which the system is thrown. These facts call upon us to reflect with admiration and gratitude, regarding the power and goodness of God, in preserving the wonderful uniformity in the constitution of the atmosphere, and thus rendering it alike congenial to the welfare of the animal and vegetable creation; it is indeed, "the breath of life!"

Chemistry discloses that nitrogen and oxygen being simultaneously present in the atmosphere, but in very unequal proportions, the negative property of the larger weight of nitrogen, restrains the positive property of the smaller weight of oxygen; it is therefore, comparatively

speaking, gradually and slowly withdrawn for combination with the elements of animals and vegetables, and without morbid excitement, because their secretory organs are compelled to perform the preliminary function of seeking and eliminating the oxygen from its admixture with the nitrogen. In connexion with this subject it may be remarked, that unless the large weight of negative nitrogen were existent in the atmosphere, all the materials which are now advantageously employed as sources of fire and artificial light, would unprofitably consume with a degree of rapidity entirely disproportionate to their abundance upon the earth, or to the limited power of man to extract them from its strata.

The accurate analysis of atmospheric air and the eduction of its chief elements oxygen and nitrogen, is a difficult operation which can only be successfully conducted by persons well skilled in the knowledge of elementary substances and the manipulations required for their treatment; but the principle on which the analysis is conducted admits of simple explanation. It is a popular fact that some metals, especially iron, copper, zinc, tin, and lead, when heated for a time, lose their distinctive lustre, and become tarnished; Chemistry proves that the heated metals are excited to unmix the portion of atmospheric air by which they are surrounded, and to combine with its oxygen to produce oxides which constitute the tarnish on their surfaces, whilst having no affinity for the nitrogen, it is liberated in its elementary form.

The liquid metal mercury, when heated in air, thus tarnishes or oxidizes in a most remarkable manner; and as, on account of its liquidity, and requiring but a moderate elevation of temperature for the phenomenon to ensue, the experiment can be conducted in glass vessels, it is generally chosen for effecting the analysis of air.

A portion of mercury is poured into a glass flask or globe, containing a certain volume of air; means are con-

trived for preventing either the metal or the air from escaping therefrom; the apparatus is then exposed to heat, and after some hours the original volume of the air is found to be diminished, the heat is continued until the volume of the air be no further diminished, and during the operation the brilliant liquid mercury is observed to become incrustated with a dark red crystalline solid.

A considerable volume of aëriform matter yet remains in the glass apparatus, and upon examination it is discovered to be nitrogen, incapable of oxidizing a metal, incapable of supporting flame, and incapable of sustaining life; it has been educed from the volume of the air by the heated mercury exerting chemical affinity for the oxygen with which it was mingled.

The red crystalline solid substance is an oxide of mercury containing the oxygen that was gaseous, and the mercury that was liquid, both combined in the annexed equivalent proportions, namely;—oxygen, $8 \times 2 = 16$ + mercury 200 = oxide of mercury 216; this was formerly called red precipitate, on account of its colour, and falling on the glass in which its formation took place.

This oxide of mercury, if exposed to a stronger degree of heat than that required for its production, undergoes decomposition, the mercury is educed in its liquid state, and the oxygen is educed in its gaseous state; capable of oxidizing a metal, capable of supporting flame, capable of sustaining life for a short time; and it is discovered, upon mingling the oxygen with the nitrogen in the same proportions as those in which the one was indirectly, and the other directly, educed, that the mixture will constitute the volume of the original air upon which the operation was conducted: thus by analysis and synthesis, proof is gained that oxygen and nitrogen, in a state of intimate mechanical mixture, constitute the chief elements of atmospheric air.

The leading characters of these two extraordinary gaseous

elements, and other useful information, may be learned from the following experiments which only require time and attention for their successful performance.

Take a clean and dry Florence flask, then select a sound soft cork that will accurately fit its mouth, and having done so, remove the cork; obtain a stick of phosphorus about one inch long, shake it from the vial in which it is kept with water,—on account of its spontaneous inflammability,—into a cup, then insert the point of a pen-knife into the stick of phosphorus, and thus lift it on a dry cloth, press it very gently that the water may be absorbed; ascertain that the flask is cold—indeed, if convenient, it is as well to plunge its bulb into ice-cold water a few minutes, then remove it and wipe it dry—hold it by its neck in a horizontal position, then insert the stick of dry phosphorus from the pen-knife into its mouth; let the phosphorus glide gently into its bulb; lastly, carefully cork the flask, and place it to stand on a ring; repeat the whole operation with another flask, &c., but direct attention to the first for the present.

Phosphorus has a strong affinity for oxygen, and will slowly combine with that of the volume of air contained in the flask, and exhibit the phenomenon of combustion; thus, upon darkening the apartment in which the experiment is performed, a beautiful lambent flame, like that of the glow-worm, will be observed emanating from the phosphorus; let the flask remain at rest for twelve hours, then with the left hand, hold and place its neck under water contained in a large finger-glass or basin; whilst in this position, with the right hand take hold of the cork under water, turn it carefully and gently round and round, using at the same time a slight pulling force, until it be fairly loosened and removed; at that moment water will ascend to a considerable height within the flask, and the phosphorus fall into the basin.

In a former experiment on the expansion of air by heat,

page 79, when the mouth of a flask was immersed in the water contained in a finger-glass, the water only rose a very little way into the neck, and this was due to the elasticity of the air within, yielding to the pressure of the water without, but in the experiment now before us the water rises from the basin to a much greater extent; this cannot be wholly due to the elasticity of the æriform matter that the flask contains; there is no mechanical force exerted by, or within the flask to pull up the water, therefore the cause of the phenomenon remains for explanation.

Chemistry proves that atmospheric air, when experimented upon in reference to the measure or volume of its elements, without regard to their weight, as at page 20, consists of one measure or volume of oxygen, and four measures or volumes of nitrogen; accordingly during the inclusion of the phosphorus in the volume of air confined in the flask, a portion of the element has slowly burned by exerting affinity for the whole of the volume of the oxygen, and has produced a few drops of an acid compound called phosphorous acid.

Such being the case, there is a deficiency in the original volume of the air, four volumes of nitrogen alone remaining, and when the cork is removed from the mouth of the flask under water, air cannot enter to supply that deficiency; but it can exert pressure upon the surface of the water, and force a bulk of it upwards into the flask exactly equal to the volume of the oxygen abstracted by, combined with, and condensed into a liquid form by the affinity of the phosphorus.

The endeavour of the external atmosphere to press forward water into the flask, caused the cork to be so firmly fixed, and to require some force for its removal; and if the mouth had been fitted with an accurately ground glass stopper, this would have been so firmly fixed by the invisible, though ponderous atmospheric power, that the strength of the fingers could not have caused its removal.

However, the cork being removed, let it be again lightly inserted, then lift the flask away from the basin, and place it on a ring; kindle a taper attached to the end of a wire as already directed, page 81, remove the cork from the mouth of the flask and introduce the taper, its flame will be effectually extinguished, and thus evidence gained of the leading characteristic of nitrogen; remove the taper, insert the cork, and set the flask carefully aside.

A small animal introduced into a volume of nitrogen would instantly die; the fact has been ascertained for the purposes of true philosophy, and is fully established; there is no occasion whatever to repeat the experiment wantonly; a true philosopher never performs experiments on the death or torture of animals by azotic or other agents, after their effects have been once reluctantly ascertained.

Uncork the other flask under water, exactly as the first, close its mouth with the thumb, lift it out of the water to its usual position, remove the thumb, then pour the water from the flask into a glass measure, note its bulk, then return it to the flask, and add to it four similar bulks of water, the flask will become nearly full; thus proving that the volume of oxygen abstracted from the air by the phosphorus was equal to one-fifth, and the nitrogen educed was equal to four-fifths of the original volume of the air submitted to the analytical experiment.

Having succeeded in ascertaining the leading property of nitrogen, an experiment can next be undertaken for determining that of oxygen.

Procure a small chafing dish, make a charcoal fire therein; select a small dry flask, twine a narrow strip of woollen cloth half a yard long around its neck, and fasten it to serve as a non-conducting handle by which it may be lifted when heated, put into the flask a quarter of an ounce of oxide of mercury—red precipitate—hold the flask about a foot above the burning charcoal, turn it round and round that the bulb may gradually become warmed, and bring it

closer and closer, until it fairly rest upon the fuel, then cut three or four very narrow slips of deal about a foot long.

As the flask becomes heated the oxide of mercury will change from red to black; this is a mere mechanical alteration of its crystalline arrangement, by which it is rendered incapable of reflecting the red rays of light, and endowed with the property of absorbing all the coloured rays of light; remove the flask from the fire, and set its bulb on a heap of dry sand contained in a saucer; as the flask cools, the mechanical arrangement of the crystalline oxide will be restored, and it will again reflect the red rays of light; when this fact is ascertained, restore the flask to its original situation on the fire.

As the heat increases the oxide will again appear black, and soon afterwards a grey film will adhere to the upper interior part of the flask; this will gradually increase in intensity, and then divide into minute, but brilliant metallic drops; when this phenomenon happens, kindle the end of one of the narrow slips of deal, and quickly thrust it into the mouth of the flask, the flame will be found to burn with greatly increased splendour; remove the slip, and in the course of two or two or three minutes again introduce it, the end having only a bright glowing cinder; this will instantly kindle into a brilliant flame upon touching the contents of the flask, which may then be removed from the fire to the heap of sand, and its mouth accurately closed with a cork.

The explanation of the whole phenomena displayed by the experiment is as follows:—at a certain degree of heat the oxide of mercury is chemically changed, heat excites repulsion to ensue between its elements, they part asunder, the mercury being volatile rises in vapour, which first condenses within the upper and colder part of the flask as a grey film, this consists of an infinite number of metallic globules, so extremely minute as to be incapable of reflecting white light; as they increase they coalesce into

larger globules of the metal, which are distinctly perceived, being sufficiently large to reflect white light, and so shine with true metallic lustre.

The oxygen thus freed from union with the mercury is simultaneously elicited in its gaseous form, expels the volume of air that the flask originally contained, occupies its space, and then displays the phenomenon of energetically supporting and inducing flame, which is the most striking characteristic of this important and universally diffused elementary substance, the discovery of which enlightened and changed the whole previous arrangement of the laws of Chemistry.

Having effected the analysis, we may next proceed with the synthesis of atmospheric air, at least so far as its chief elements are concerned.

Provide an oval tub or pan, its greatest diameter being about eighteen, its smallest twelve, and its depth six, inches, pour water therein until it be filled within an inch of its brim; then sink a saucer to the bottom near one end, place the arrangement upon a table with this end to the right hand.

Provide a yard or two of soft lead wire, about an eighth of an inch in diameter—it is commonly used by gardeners for fastening plants to trellis-work—then proceed to wind this closely around the neck of the first flask which still contains the nitrogen, and fasten the wire firmly with string that it may not slip.

Having done this, take the flask in the left hand, to the left hand end of the tub or pan; sink its neck two inches beneath the water, then hold the neck firmly, and gently withdraw the cork; relax the hold of the fingers, and the weight of the lead wire will cause the mouth of the flask to sink and touch the bottom of the tub or pan, and its bulb to remain upright; this is the only object of loading the neck of the flask with the lead wire; take the flask containing the oxygen, hold it in the left hand, then sink its neck

two or three inches beneath the water, exactly above the saucer, hold its neck firmly, and with the other hand gently remove the cork; the whole of the oxide of mercury, and part of the mercury, will fall into the saucer, and can be collected when the experiment is concluded, then, still keeping the neck of the flask beneath the water, grasp its bulb gently, yet firmly, in the right hand.

Grasp the bulb of the flask containing the nitrogen gently, yet firmly, in the left hand, raise it steadily, that its mouth may be two inches beneath the water, hold it in such position, and advance the oxygen flask towards it, until their bulbs nearly touch, then depress the oxygen flask in a direction inclining greatly to the right hand, that its mouth may come beneath and touch that of the other; continue to do so until bubbles of oxygen arise into the nitrogen flask and displace the water that it contains, until it be quite full; then lift away the oxygen flask, set it aside, as no longer needed, but carefully insert the cork of the nitrogen flask, wipe its exterior dry, and lift it away to stand on a ring as already directed,

This flask now contains a mechanical mixture of nitrogen and oxygen, and by removing the cork, and introducing the lighted taper, its flame will be neither extinguished nor increased, but will burn with the same brilliancy and steadiness, as in the external atmosphere.

These analytical and synthetical experiments upon atmospheric air, require time and care for their successful performance, but will amply repay the operator for his patience and attention by the useful and interesting information they present regarding the fact that the air, which was for so many ages styled an element, is chiefly a mechanical mixture of the gaseous elements nitrogen and oxygen.

This important subject being for the present concluded, another phenomenon of Spring, upon which the germination of seeds and the growth of plants depend, now demands our attention. The thaws and floods of February, leave the

earth saturated with water, and unfit for the reception of seeds, but the swift aerial currents, familiarly known as "March winds," are ordained to evaporate the surplus of this humidity, and to dry the soil sufficiently for the husbandman to commence his active labours in the field.

In the ensuing month, the evaporated water condenses into drops, and descends as the showers of April, to fertilize the earth from whence it ascended ; hence the origin of the proverb, " March comes in like a lion, and goes out like a lamb," meaning, that the weather at the beginning of the month is generally rough and boisterous, but at the end, softened and subdued. Another proverb says, " A peck of March dust is worth a king's ransom," because it indicates to the husbandman the probable continuance of dry weather, and upon the proper dryness of the soil for the reception of seed at this season, so that it may not rot and become worthless, depends the produce of the autumnal harvest.

" A dry and cold March never begs its bread ;" this homely saying, meaning, because it prepares the earth for seed time ; but " A wet March makes a sad August," another homely saying, meaning, that urged by necessity, the husbandman is compelled to cast seed into the ground whilst it is saturated with the waters of February, therefore much is spoiled, and yields no crop in August.

It is popularly said, that " The late spring makes the fruitful year," for if very mild weather happen in March, vegetation assumes the aspect which properly belongs to April ; buds and blossoms are pinched by the night frosts, and are either killed, or so injured, that they produce neither flowers nor fruit in due season, and hence the saying, that " March flowers make no summer bowers."

The foregoing proverbs and sayings must not be despised or neglected for their homeliness ; they convey philosophical truths, and prove how accurately our ancestors studied the phenomena of the Four Seasons, although undirected by refined scientific knowledge.

In the science of Meteorology, which has for its object the examination of phenomena appertaining to the atmosphere, the forms of clouds has attracted much attentive study, and they have been conveniently classed under four principal heads, viz., 1, the cirrus; 2, the cumulus; 3, the stratus; and 4, the nimbus.

The cirrus, or mare's tail, is a very light and fleecy cloud, closely resembling the form of a lock of hair, or a feather; the cumulus, or summer cloud, is usually massive and rounded in form, sometimes of moderate, and at others of prodigious extent, and occasionally appearing in the horizon, having a magnificent resemblance to huge mountains capped with snow; the stratus, or earth-cloud, is a horizontal misty cloud, sometimes seen comparatively near the earth, and often crossing the middle regions of mountainous or hilly districts; the nimbus, or rain cloud, is uniformly tinted grey, and fringed at its edges, when these are displayed, but usually extends over the entire sky.

The region of clouds may be considered as a zone extending in the atmosphere from one to four miles above the surface of the globe; the clouds which float at the lowest elevation are those called the stratus, and at the greatest elevation are those called the cirrus.

There are some modifications and combinations of the four classes of clouds, known as the cirro-cumulus, cirro-stratus, and cumulo-stratus, which frequently appear throughout the seasons, and, by the diversity of their form and beauty, conduce to the magnificent scenery of the heavens and the earth.

Chemistry can offer no satisfactory explanation regarding the formation of clouds, but so far as researches have been carried, they tend to the conclusion, that clouds do not consist of actual drops of water, but of myriads of excessively minute and thin vesicles of water—like soap bubbles—thus they are enabled to hover at a small elevation for hours, and to transport their aqueous store far into the level country, or to

the tops of mountains, when the vesicles, suddenly breaking, and their watery films coalescing into drops, which the air cannot support, they fall in showers upon the earth; many of its localities cannot derive their requisite supplies of moisture in any other way.

It is also supposed that clouds are formed by the meeting and blending together of two volumes of air, both being saturated with aqueous vapour, but having different degrees of temperature; the exact physical cause of the phenomenon is at present a mystery.

"He causeth the vapours to ascend from the ends of the earth; He bindeth up the waters in the thick clouds, and the cloud is not rent under them."

"Canst thou tell the balancings of the clouds, the wondrous works of Him which is perfect in knowledge?"

To minds duly prepared, the observation and study of the "magnificent history of wisdom and intelligence which is written in legible characters both in the heavens and on the earth," is an inexhaustible source of happiness which can never prove incompatible with the exalting influence of the Scriptures, since both emanate from One Omnipotent Being, as faithful messengers to direct the reverent and humble approach of man towards the throne of His mercy and of His power.

The Scriptures do not contain a single prohibition regarding the acquisition of wisdom and understanding concerning the phenomena of the universe; on the contrary, they first set forth the rudiments of such philosophy, in the circumstantial language of history, then enjoin its search in the sublimest strains of poetry, and lastly extol the pleasures and advantages of its discovery, in the attractive charms of proverb and of song.

First, as regards the rudiments of philosophical knowledge; secondly, as enjoining its search; and thirdly, as extolling its discovery, the Scriptures thus testify.

"In the beginning, God created the heaven and the

earth," *et seq.* "And God saw everything that He had made, and behold it was very good."

"The works of the Lord are great, sought out of all them that have pleasure therein."

Worthy, that is, of being inquired into, and studied by all who delight in obedience to His will, and such only can appreciate His power.

"Happy is the man that findeth wisdom, and the man that getteth understanding."

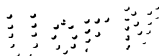
The happiness of the man who finds pure knowledge is here—to suit human comprehension—likened to the ordinary elation and gladness of the man who directly finds a pure vein of precious metal, or indirectly succeeds in getting or drawing it out in purity and value from an ore, by his own application and labour; the terms "finding" and "getting," as in remote ages, are even now employed, for denoting such discoveries.

The inestimable worth of pure knowledge is then placed in direct and powerful contrast with the insignificant value of metallic riches.

"For the merchandize of it is better than the merchandize of silver, and the gain thereof than fine gold."

Truly inestimable are the varied phenomena presented in the wide realms of the creation throughout the revolving year, and such as we cannot interpret by our own limited talents, still awaken in our minds the most glowing sentiments of gratitude and admiration towards the Creator.

Thus the physical cause of the blue colour of the sky cannot be satisfactorily interpreted through the medium of science, and yet at all seasons we acknowledge its surpassing beauty, more especially in spring, when the creation is awakened from the sleep of winter. The atmosphere, immediately incumbent upon the earth, has probably the power of absorbing and retaining more of the blue rays of light than that at a greater altitude; and thus, when we cast our eyes on high, we look through a volume of the densest



air, replete with blue light; so likewise if we look abroad over an extensive tract of open country, the horizon of which is formed by hills, they appear blue, or in other words they are affected by the colour of the medium through which they are viewed.

As we journey towards these hills, their blue colour will gradually disappear, and their ordinary colours will ultimately appear, and then, standing on the hills and looking from them towards the spot from whence we journeyed, it in turn will appear blue.

"The ridge called 'Blue Mountains,' in Australia, another of the same name in America, and others elsewhere, are not really blue, for they possess all the diversity of scenery which their climates can give; but to the eye which first discovered them, bent on them generally from a distance, they all at first appeared blue, and they have retained the name."

The air contained in a spacious hall or room, is too small in volume to affect the eye with an impression of blue colour, and all objects placed therein appear of their natural tints; the same as an alabaster ornament will appear beautifully white when viewed through a thin glass shade, but will gradually appear green upon being covered with three or four additional shades, although they are of equal thickness and transparency; and if several more be employed, the ornament will ultimately become invisible.

The red appearance of the evening and morning sky, so popularly known as indicative of fair and foul weather, was chosen by the Saviour of mankind as the medium of a powerful reproof to the benighted vanity of the worldly-wise who had no perception of the faith.

"When it is evening ye say, it will be fair weather, for the sky is red.

"And in the morning, it will be foul weather to-day, for the sky is red and lowering.

"O ye hypocrites, ye can discern the face of the sky; but can ye not discern the signs of the times?"



The science of Astronomy proves that, in consequence of the refractive or light-breaking power of the atmosphere, the sun is visible for a considerable time after actual sunset, and is also visible for a considerable time before actual sunrise; the science of Chemistry proves that, at actual sunset, the surface of the earth becomes cooled—how, will be considered hereafter—and the watery vapour present throughout a considerable height of the atmosphere, immediately enters into incipient condensation. It is therefore presumed that the red glow of light so often apparent at sunset, may depend upon the vesicular vapour reflecting the red rays more powerfully than others, since it is found, if light be transmitted through ordinary steam—which, when visible, is in the state of incipient condensation—that it assumes a deep orange or red colour.

At sunset the red colour of the sky indicates fine weather on the morrow; although aqueous vapour is present in the atmosphere, it is probably only on the verge of incipient condensation, or is not sufficiently thickened or condensed to form rain clouds, and this progressive transition of large volumes of the atmosphere to the temperature of incipient condensation, can only occur in calm weather at sunset, and not at sunrise.

The red and lowering appearance of the morning sky which indicates foul weather, probably depends upon such an excess of aqueous vapour being present in the whole atmosphere, that its condensation is proceeding with sufficient power to form rain-clouds in the more elevated regions, in opposition to the immediate tendency of the rising sun to cause their dissipation, they accordingly reflect the red rays of light abundantly, and announce the speedy fall of showers of rain.

“ In the morning, in fine weather, the volume of the atmosphere directly incumbent upon the earth is alone saturated with humidity, the volume of the atmosphere at a considerable altitude is comparatively dry, and the light at sun-

rise is not materially affected or is grey; the vapours which, during the reversion of the process, might probably reflect the red rays, are not elevated until the action of the sun upon the surface of the earth has continued long enough to impart a sensible warmth, by which time the moment of sunrise is past, and the sun has ascended above the horizontal vapours."

Our ancestors were close observers of natural phenomena, and therefore originated many sayings and proverbs, some of which have been presented, and we find another concerning the appearance of the skies that we have just considered and endeavoured to interpret.

"An evening red, and morning grey,
Will set the traveller on his way;
But an evening grey, and a morning red,
Will pour down rain on the traveller's head."

In the absence of accurate artificial means, the husbandman invariably consults the appearance of the evening and morning sky, the actions of animals, and the forms of flowers, and is thus enabled to foretell the probability of fair or foul weather.

The sky guides him according to the foregoing proverbs, and if in the morning, cattle low more than usual, and stretch forth their necks, and snuff the air with extended nostrils, he expects rain; if the chickweed be quite open, and if the trefoil and bindweed stand out boldly, no rain will fall; many other flowers close their petals against the approach of rain, but these are the most common, and the most easily observed.

The quantity of rain that falls in different parts of the world is subject to much variation, but, generally speaking, it is less abundant in high than in low latitudes, thus, for example, the annual fall of rain at St. Petersburg amounts on the average to a depth of 17 inches; in Great Britain to

25 inches; at Bombay to 80 inches; and in the island of Tahiti to 160 inches.

There are some extensive districts of the earth in both hemispheres upon which rain seldom or ever falls, and are therefore parched and desolate; as exemplified in the Great Desert of Africa, and the flat regions of Northern Peru; but the Creator has beneficently ordained some rainless districts to be subject to periodical inundations from the rise and overflow of mighty rivers, and thus to become fertilized, as for example, those parts of Egypt which are watered by the river Nile.

These waters saturate the earth, and then subside, leaving abundance of sediment or mud, consisting of finely divided earthy and organic matters which act as powerful stimulants to the germination and growth of seeds and grain.

Allusion is made to this phenomenon in the following beautiful metaphor: "Cast thy bread upon the waters, and thou shalt find it after many days." In oriental countries bread is synonymous with rice, which is cast upon the soil, saturated by the inundation, and, though lost for a time amidst the moisture, ultimately appears in due season, as a plenteous harvest.

Many local causes affect the quantity of rain that falls on a particular region, such, for instance, as the nature of its surface, the prevalent wind, the proximity of the ocean; and, generally speaking, a larger quantity of rain falls on mountainous and thickly wooded islands than upon any other terrestrial surface. Chemistry explains that such phenomenon depends upon the large amount of aqueous vapour which arises from the surface of the surrounding ocean, being wafted inland and there condensed by the cold elevated surfaces of the mountains and the vegetation, and afterwards descending in copious and heavy showers of rain; this is the case as regards the enormous annual fall of rain in the island of Tahiti, it being mountainous, and abounding in luxuriant vegetation. The district of Peru already men-

tioned, although bounded on the one side by the Pacific Ocean, and on the other by the lofty Andes, is an arid and sterile plain, because its surface is so hot that it cannot condense the aqueous vapour wafted over it by the winds from the ocean; it therefore remains a rainless district, but the vapour when it ascends to the cold summits of the mountains, is rapidly condensed, and accordingly abundance of rain is precipitated.

In some countries the flat plains are rainless districts, though bounded by lofty mountains or hills close bordering upon the ocean or sea, because the aqueous vapour wafted by the atmosphere is immediately arrested and condensed by their cold summits, upon which abundance of rain consequently falls, and little or no aqueous vapour can then be wafted over the flat inland plains to condense, and refresh them with rain: this is the case with the rainless districts of Arabia.

The rainbow that so frequently adorns the watery clouds as "the token of the covenant between God and man, that the waters shall no more become a flood to destroy all flesh," must be esteemed as the most beautiful atmospheric phenomenon that is beheld throughout the Four Seasons; it, however, does not admit of explanation through the medium of Chemistry; its interpretation belongs to the very highest departments of the science of Optics, and then very probably, it is only known in part, but even such part, could it be here admitted, would more than occupy the remaining limits that are assigned for the consideration of the actual chemical phenomena of spring, but the phenomenon is so beautiful, as to tempt us to quit the direct province of Chemistry for a few minutes, and trespass upon that of Optics, for unfolding the probable physical cause of the rainbow in concise terms.

The rainbow invariably appears in the part of the heavens which during the day is directly opposite to the sun, and whilst rain is falling between the dark clouds

in that quarter, and the solar beams in the other; these under most circumstances, impinging upon the pellucid rain-drops, will either directly pass through them in right lines, or if refracted from such course by the impact and emergence, will nevertheless resume it, and pass onward as colourless light.

Under certain conditions, the solar rays, impinging upon pellucid rain-drops, will not only pass through them, or be refracted by them, as described, but upon emergence therefrom, a portion of the rays will continue to pass onward as colourless light, as after ordinary refraction, whilst another portion deviates from such path, and is further refracted or broken into seven extraordinary coloured rays as mentioned, page 52, at a very early period of our investigations.

In this extraordinary chromatic refraction or analysis of solar light, the violet coloured rays depart farthest from the path that the unaltered rays would have pursued, and the red coloured rays keep nearest to the path that the unaltered rays would have pursued; thus the external and the internal fringes of the rainbow are formed, and they include within their arcs the remaining coloured rays in the order of their inherent refrangibility, the indigo, blue, and green, being nearest the violet; the yellow and orange, being nearest the red; thus presenting a perfect rainbow of the seven coloured rays of colourless light, or in more technical terms, the violet, indigo, blue, and green rays, are the most refrangible, whilst the yellow, orange, and red, are the least refrangible rays of solar light, therefore the rainbow is said to present a magnificent natural example of its analysis.

When a single and perfect rainbow appears, its interior fringe is red, and its exterior fringe is violet, but a double rainbow is most frequent—a phenomenon that is of one bow within another—and then not only are the colours of the inner and smaller, or the primary bow, more vivid than those of the outer and larger, or the secondary bow, but they are

exactly in the reverse order, the interior fringe of the inner bow being violet, and its exterior fringe being red.

The form of the double rainbow is represented in the accompanying engraving, the dark shading of the bows de-



Fig. 16.

noting their respective fringes of violet light, as the employment of surfaces to reflect individual colours is impracticable in this department of art; indeed, when it is considered that the effect of an engraving depends upon the total reflection of one portion of colourless light, by the surface of the paper, and the total absorption of another portion by the surface of the ink, it seems extraordinary that simple engravings should convey to the eye any correct notion of the appearances of surrounding objects.

One more example of a scientific truth couched in homely guise, is presented by the following ancient and popular proverb :—

“ A rainbow in the morning is the shepherd’s warning,
A rainbow at night is the shepherd’s delight.”

“ This old proverb is generally correct, as a rainbow can only occur when the clouds containing or depositing the rain are opposite to the sun ; and in the evening the rain-

bow is in the east, and in the morning in the west ; and as our heavy rains in this climate are usually brought by the westerly wind, a rainbow in the west indicates that the bad weather is on the road by the wind to us ; whereas the rainbow in the east proves that the rain in the clouds is passing from us."

"As an indication of wet weather approaching nothing is more certain than a halo round the moon, which is produced by the precipitated water, and the larger the circle, the nearer the clouds, and consequently the more ready to fall."

All things demand equal attention from him who truly loves and desires knowledge ; thus, the foregoing explanation of the homely proverb, emanated from the most enlightened philosopher who ever devoted his talents to the fascinating science of experimental Chemistry.

Educated in strict accordance with the inflexible laws of inductive philosophy, constantly inferring and collecting general results, general facts, and laws, from a number of particular instances, carefully established upon actual experimental evidence, this philosopher proved the utility of Chemistry when judiciously applied towards increasing the resources, and adding to the welfare of man, and demonstrated its importance as the interpretative medium of many wonderful natural phenomena, for the intellectual guidance of man towards the "First Author of Beauty who hath created them all."

God for the fulfilment of His inscrutable purposes has been pleased to take the spirit of this true philosopher from the world that it was permitted for a few years to enlighten and adorn ; the voice that eloquently described the wonders of the Creation, is hushed, and the hand that experimentally demonstrated them, is closed in the cold grave.

But those words of fervour, and works of skill, are faithfully remembered, and zealously guarded by his disciples

who are yet permitted to remain ; and as they follow at a vast distance, the footsteps of their late master, they endeavour as he did, to keep the laborious yet secure path that is permanently illuminated by the steadfast sun of experiment, and to shun the seductive yet dangerous maze that is transiently lighted by the erratic meteor of hypothesis.

Reliance may always be placed upon the light of experiment, because its rays can only emanate from the mirror of truth. Theory and hypothesis, it has been well observed, impose upon the imagination like the "mirage" of the Egyptian sands, but like this illusion they must pass away ; they may present to the eye a magnificence as seducing as the "fata morgana" oftentimes witnessed upon the coast of Calabria, in which the most beautiful landscapes, crowned with picturesque villages, superb palaces and massy towers, seem to possess a real existence. All is but an aërial phantom ; the enchanted scene changes with the least shifting of the light, or the ruffling of the sea, melting away like a dream of the night ; so ultimately vanish all systems of philosophy and science that are not founded upon the solid basis of induction.

Attention must be now directed to some other phenomena which are conducive to the harmony and order of the creation, and which admit of interpretation through the medium of chemical science.

The porous surface of the earth has been shown to be peculiarly fitted for the reception of water, and for its accumulation as springs ; but these benefits could not ensue if the earth were a good conductor of heat, because the imponderable agent would then gain access throughout its strata, and quickly vaporize the whole of its treasured moisture.

The Almighty has beneficently created the earth of materials capable of absorbing heat powerfully, though incapable of conducting it to any great extent ; the heat

therefore chiefly remains at or near the surface of the earth, where it is needed for the welfare of animal and vegetable life.

Thus in summer, when the surface of the earth is very hot, if we excavate only to the depth of a few feet, it is found to be several degrees colder; and in winter, when the surface is covered with snow, if we proceed to a similar depth it is found to be several degrees warmer, and invariably above 32° , or the clods of earth, thrown out by the spade, instead of being soft and moist, would be hard and dry as ice.

Thus the imperfect or bad conducting power of the earth, as regards heat,—cold being only an inferior degree of heat,—is the reason that springs of water neither vaporize in summer, nor freeze in winter.

The coolness of a draught of water drawn from a deep well in summer, and its comparative warmth from the same source in winter, affords a familiar example of the point under examination; indeed during the intense cold of winter, as the water of a deep spring gushes to the surface of the frosted earth, it actually steams, or in more chemical language, its warm vapour undergoes condensation by the cold atmosphere into which it issues.

At the depth of 100 feet from the surface, the temperature of the earth is the average temperature of the climate, and differs with the latitude; thus at Wadso, in Lapland, it is 36° , at St. Petersburg 40° , in London 52° , in Paris 54° , in Rome 64° , and in Cairo 70° .

Air and water are non-conductors, and the earth is an extremely imperfect conductor of heat; good conductors of this most extraordinary agent do not, generally speaking, occur abundantly upon the surface of the earth, or they would render it sterile, but as metallic treasures deeply hidden in its bosom where there is no life, and from whence they are extracted and rendered subservient amongst thousands of other uses, to the formation of the ploughshare

and spade for tilling the ground, and the scythe and sickle for reaping its produce. A few experiments regarding the difference between good and bad conductors of heat can be easily performed, and they will present much useful information.

Spread fine iron filings evenly to the depth of half an inch over one half the surface of a metallic hot-water plate, and fine dry sand evenly to the same depth over the other half, place a lump of pomatum about the size of a pea on each, then pour boiling water through the proper aperture in the rim of the plate until the receptacle be nearly filled.

The iron and the sand will be thus exposed to the same degree of heat; but they will not conduct it with the same facility, as will be proved by the pomatum on the iron melting in a few seconds, whilst that on the sand will remain without melting for many minutes.

The difference between the conducting power of a metal, an earth, and an earthy compound, may be strikingly illustrated in the following manner:—provide solid cylinders of iron, sandstone, and chalk, let them be one inch in diameter, six inches in length, and perfectly flat at their ends; place a cup containing about an ounce of pomatum upon the warm hob of the grate; when the pomatum is melted, dip into it for about half an inch one end of the iron cylinder, then lift it out; a portion of pomatum will adhere and quickly become solid, because the iron by good conducting power deprives it of the heat which caused its fluidity.

Dip one end of each of the other cylinders in the same way, they will absorb a considerable portion of the melted pomatum, and some time will elapse before it will become equally solid with that on the iron cylinder, because neither the sandstone nor the chalk have sufficient conducting power to deprive it of heat with a similar degree of rapidity.

Dip the end of each cylinder again, then lift out each, and when the pomatum becomes solid dip each again,

and again lift out; thus proceed until each has obtained an equal coating of pomatum, then allow them to cool. When perfectly cool, place the three cylinders to stand with their coated ends uppermost, at equal distances upon the surface of a metallic hot-water plate, then pour boiling water into its receptacle, as already directed.



Fig. 17.

In the course of a few minutes the iron will manifest its good conducting power, as regards heat, by the pomade melting from its upper end, although fully six inches distant from the source of the heat; whilst the sandstone and chalk will manifest their

bad conducting power by the pomade remaining solid at their upper ends during the whole time that the water is cooling down to the temperature of the atmosphere.

When heat is applied to any point of a good conductor, its entire mass will eventually become elevated in temperature; whilst on the other hand, with a bad conductor, the heat will chiefly remain upon the point to which it is first applied, and the great part of the mass will not become elevated in temperature.

For example, when the pomatum has entirely melted from the upper end of the iron cylinder, if this be felt, it will be found nearly as hot as the lower end; if the cylinders of sandstone and chalk be felt, their lower ends alone will be found hot, and by moving the point of the finger slowly upwards, the limited height to which they have conducted heat will become sensible.

By reversing the arrangement of the experiment, namely, applying heat at the upper, instead of at the lower ends of the three cylinders, it can be proved that the conducting power of the iron and the bad conducting power of the sandstone and chalk, are neither affected nor modified.

Let the iron cylinder be again coated with pomatum, but pare away all that covers its circular extremity, so that it may now stand firmly upon this, and have only a ring of pomatum about half an inch wide around its circumference; do the same with the cylinders of sandstone and chalk, then set the three at equal distances apart, within a circle similar in diameter to the bottom of the hot-water plate, on a circular board equal in diameter to the top of the plate, that they may form a tripod for its support; this arrangement must be made upon a steady table; then remove the plate without disturbing the cylinders, pour in boiling water as directed, and carefully replace it to stand upon their upper ends.



Fig. 18.

The three cylinders will thus be subjected to heat applied from above instead of from below, as was the case in the last experiment; but this reversal will cause no difference in good conducting or bad conducting power, as will be proved in the course of a few minutes by the ring of pomatum melting from the lower

end of the iron cylinder, whilst the rings upon the lower ends of the sandstone and chalk cylinders will remain solid, during the cooling of the water, to the temperature of the atmosphere.

Solar heat naturally impinges upon the surface of the earth, and there chiefly remains, as it cannot progress downwards on account of the imperfect conducting materials of which the earth is constituted.

During a hot day the surface of a sandy soil becomes dry and dusty; if this be removed, damp sand appears at the depth of a few inches, and proves that heat has not been conducted downwards to any considerable extent.

As an example of the bad conducting power of earthy

substances in the form of porous dust and scorias, it may be mentioned that the shepherds in the higher regions of Mount Etna are accustomed to preserve snow by strewing over it a layer of volcanic sand a few inches thick; this earthy matter effectually prevents the heat of the sun from penetrating; the snow is withdrawn from time to time, and allowed to thaw in the direct sunshine, and thus form water for the use of the flocks; such water is better than none, certainly, but not well fitted for the support of life, for a reason that will appear hereafter.

The reason that heat does not accumulate to a destructive extent upon the surface of the earth, will appear when the chemical phenomena of another season are under consideration.

The vital force which is exerted during the germination of seeds, and the growth of plants, is a phenomenon well calculated to arrest the attention of a philosophic mind.

When a seed is buried in the earth, it might be anticipated that the hard and solid particles of the soil would crush the delicate and fragile germ of vegetable life at the very moment of its development; but the Creator has otherwise ordained.

Moisture from the soil is attracted by the capillary cells and membranes of the seed, causing it to swell with sufficient force to thrust aside the particles of the soil, and make them yield place to the increased bulk, and although it is softened by the aqueous absorption, it is adequate to the strength required for the purpose, and sustains no injury from its exertion—like as a soft hand can thrust aside hard obstacles without being hurt; this mechanical action having reached its maximum the embryo is aroused from its dormant state, chemical action is then induced, and under the influence of vitality causes the water to transmute the amylaceous bulk of the seed into gum and sugar, as food for the germ, that it may grow and increase in strength, and further thrust aside the soil in search of other nutriment.

Once endowed with vitality, the powers of the organic structure become superior to those of inorganic matter, for example,—the radicle sends forth soft and tender filaments to penetrate between hard solid stones, in search of nutriment, contained within their interstices, and these filaments, in obedience to gravitation, descend considerably beneath the surface of the soil, to form a steadily adherent root.

The plumula simultaneously sends forth delicate and fragile folds, having a nearly equal strength to those of the radicle, but exerted in an opposite direction, to part asunder, and lift before them the incumbent particles of their terrestrial prison, thus to emerge from it, and enter amidst the ethereal treasures of light and heat, under whose combined influence the folds are excited to burst into leaves, a perfect plant to flourish, destined in due season to “yield seed after its kind,” which is ordained in its turn to present the same routine of miraculous changes.

Fill a moderate sized flower-pot with garden-mould, sow in it a handful of cress or mustard seed, then place the bottom of a light shallow basket, to cover the mould, and to rest upon the brim of the flower-pot; leave this arrangement for a few days, until germination commence; then, as the upward growth proceeds, it will at length touch the bottom of the basket, and in the course of a few days, will fairly lift it from the brim of the flower-pot; some estimate of the vital force which is thus exerted may be formed by placing small pebbles in the basket day after day, until the vegetable begin to crush beneath the load, which can then be removed and weighed, and will probably amount to several hundred grains.

When natural or artificial obstacles of great size, solidity, and weight are opposed to the small, fragile, and light structures of plants, attraction of gravitation and of cohesion combine to render the statical power of the former, superior to the motive power of the latter; and in such cases, although the organic forces cannot directly penetrate or lift

the ponderous obstacles to their progress, they preserve as closely as possible the direction that they would have pursued if not opposed, and they will recover it at the earliest opportunity.

The futile endeavour of a plant to remove an obstacle opposed to its upward growth, and its graceful yielding to such opposition, was remarked many ages since in regard to an acanthus, on the centre of which was set a tall basket, having its top covered with a large flat stone; these two heavy impediments diverted the rising leaves of the plant



Fig. 19.

from their natural course, and caused them to assume a bending beauty of form, from the observation of which it is supposed originated the idea of the elegant Corinthian capital; in the purest style of which order of architecture the acanthus entirely surrounds with its aspiring leaves, the basket or vase

of the capital, as if attempting to raise the flat stone or abacus that covers the whole; they then turn down and form themselves into graceful volutes.

In some instances, when plants cannot remove solid obstacles, they will actually enclose them within their own structures; thus nails and stones have been found firmly embedded in the trunks of trees; some Indian nations take advantage of this fact; for the construction of their hammers, they split open the supple stem of a creeping plant, then place an oblong piece of heavy stone in the aperture, and bind it fast with the growing shoot of another plant of the same kind; by the end of twelve months the stone is firmly interlaced, the stem which bears it is cut away, and thus a rude hammer is obtained.

An instance is upon record, of a tree actually exerting sufficient vital force to break asunder an overhanging shelf of rock, and passing through the cleft thus formed, of continuing its upward growth, to a great extent.

We may now resume our investigation concerning the phenomena of germination and growth, which we quitted at the time when the seed had put forth its radicle and plumula.

The radicle sends out its fibres amidst the soil in search of moisture and soluble matters, and by an incomprehensible vital function transfers them into the body of the plant, where they undergo mysterious elaboration to form the fluid called sap.

The terminal fibres of the radicle are so minute as to require the aid of a microscope for their detection, and if injured, they will not fully exert their proper functions; therefore in transplanting, we always endeavour to avoid wounding them with the spade, by digging some distance around their probable extent, and thus carrying away with the plant, a large ball of earth through which the fibres have not as yet penetrated.

This precaution, likewise, protects the plant from sustaining those derangements of its functions which would inevitably ensue, if it were rudely torn from the earth, and suddenly transplanted to a soil physically and chemically different to that in which it originally germinated and grew; the plant will thus continue to draw for aliment upon its parent clod of earth, until its radicle be enabled to pierce beyond such limit, and thus to become gradually inured to the change of nutriment presented by the surrounding soil.

Chemistry presents many substances which are poisonous to animals; the best known of these are white arsenic — oxygen $8 \times 3 = 24$ + arsenicum $38 \times 2 = 76$ = arsenious acid 100 — corrosive sublimate — chlorine $36 \times 2 = 72$ + mercury 200 = bi chloride of mercury 272 — blue vitriol — sulphuric acid 40 + oxide of copper 40 = anhydrous sulphate

of copper 80 + water $9 \times 5 = 45$ = anhydrous or crystallized sulphate of copper 125 — and prussic acid — carbon $6 \times 2 = 12$ + nitrogen 14 + hydrogen 1 = hydro-bi-carburet of nitrogen 27, obtained by operations upon Prussian blue, hence its common name — and it is discovered, that any of these, if dissolved in water, and then applied to the roots of growing plants, will soon cause them to droop and die.

Many experiments have been made upon the destruction of the vitality of plants by such poisonous substances; the following are a few of the most remarkable.

Beans were watered with a solution of white arsenic, they faded in the course of a few hours, and in three days were dead.

A lilac was killed by the introduction of a portion of solid white arsenic into a cut made in one of its branches, and a similar effect was produced by corrosive sublimate, beans were killed by a solution of prussic acid, in the course of a single day, and deadly nightshade in four days.

An experiment can be easily made regarding the poisonous action of a metallic solution upon a plant; for example, water a succulent plant with a solution of blue vitriol, until it droop and die, then cut it to pieces with a perfectly clean steel knife, and that the poisonous cupreous compound has been absorbed by the plant and caused its death, will be evident by bright metallic copper appearing on the knife-blade.

All things, however, are so miraculously adjusted in natural arrangements, that the earth seldom or ever presents the roots of plants with poisonous substances, but in their stead, harmless compounds of lime and potassa, which, under the influence of vitality, promote the elaboration of healthy sap or vegetable blood.

Chemistry can throw but very little light upon the composition of the sap; no analysis unto which it has been subjected can be regarded as correct, on account of the difficulty of obtaining it in its normal state, or free from other juices

of the plant; the cause of its motion or circulation is also a mystery; it is observed to travel through the stem and the branches, and chiefly towards the leaves; it enters their peculiar structures as a comparatively thin fluid, containing a large amount of water; much of this, by the combined agencies of heat, light, and air, is evaporated in a pure state; thus the sap becomes thickened or concentrated, and excited to form new proximate principles, which increase the growth of the entire plant.

This evaporation of water from the leaves of plants, proves, upon close examination, to be enormous; a large sunflower lost one pound four ounces, and a cabbage one pound three ounces of water, during twenty four hours; and many plants lost one hundred times their weight of water during three months. The evaporation of water from plants may be detected by covering them with a cold dry bell-glass; in the course of a few minutes its interior will become lined with small drops resulting from the condensation of the vapour, and that the evaporation ensues chiefly from the lower surfaces of the leaves, may be shown by placing them between two cold dry plates of glass, as represented in the annexed sketch.



Fig. 20.

Water will then condense most abundantly upon the glass plate which is opposed to the lower surfaces of the leaves, their organization being the most peculiarly adapted for the transpiration of its vapour, although it has been occasionally observed that the upper surfaces of the leaves of some plants are the most active in facilitating its escape.

As evaporation thus proceeds from the leaves, they inces-

santly demand a fresh supply of moisture from the roots; and if the soil be too dry, or water be not abundantly furnished to meet the demand for its evaporation, the plant will surely sustain much, if not irreparable injury.

Plants are frequently "blighted"—as it is popularly termed—during early spring, by dry winds, for when branches and leaves first sprout forth, they are extremely succulent, and part with their water so readily, that during a dry easterly wind this loss by evaporation cannot be supplied with sufficient rapidity by the capillary vessels of the roots.

The drooping of a plant during a hot day, mainly depends upon the extreme evaporation of water that has been excited to ensue from the extensive surfaces of the leaves, and the inadequacy of the terminal fibres of the roots to collect more from the arid earth; if water be artificially added to it, or if a shower fall, the plant will revive, sometimes with extraordinary quickness, by capillary attraction being brought into active operation.

Leaves have not only the power of transpiring the vapour of water, but of absorbing it under certain conditions; thus, a plant drooping under the influence of heat, will revive if placed in a damp cellar; the leaves absorb the damp or the vapour of water there present in the air, and by its refreshing agency the plant will regain its wonted strength and beauty; the leaves, in their exercise of the functions of evaporation and absorption, are of vital importance to plants; strip them away, and the plants will suffer in health or suddenly die.

"Not only vast, but numberless," are the wondrous exemplifications of the power, wisdom, and beneficence of the Creator presented by the structure, properties, and functions of the vegetable kingdom, which have been disclosed by men "being conversant with His works, who search Him diligently, and believe their sight because the things are beautiful that are seen."

An attempt to particularize but a few of these would form a voluminous work ; they can only receive a brief general mention within these few pages.

Some plants are found to spring from the earth, to grow, to produce leaves, buds, flowers, fruits, seeds, and so having accomplished their destined end, to die and decay within the space of the revolving year : these are popularly known as annuals.

Other plants are ordained to secrete and to elaborate elements for the structure and growth of their stems and leaves during the first year of their existence, and thus to prepare for the organization and perfection of their flowers and fruits in that which next ensues ; then having completed their allotted functions of beauty and utility, they die, and in their decay, as with all organic matter, are resolved into their ultimate elements, or into new compounds thereof, which in due season are again commanded to arrange themselves in vital structures ; such plants are called biennial.

There are plants, shrubs, and trees, that grow and flourish for many years, and constantly elaborate elements to increase and perfect their structure for the benefit of man, and frequently attain a great age, as exemplified by the oak of Britain, which is nearly sixty years in attaining perfection, and then will live and flourish beyond a century ; the yew also may be cited as an example of these vegetable forms which are termed perennial.

There are plants whose leaves wither, fall, and decay at the close of autumn, and remain with denuded branches throughout the winter, until clothed with new foliage in the ensuing spring ; other plants are never destitute of foliage throughout all the vicissitudes of the Four Seasons ; hence the former are commonly known as deciduous, and the latter as evergreen.

The Creator in His beneficence has ordained these trees to grow where their presence is of the most importance to

the welfare and relief of man and animals; thus trees deciduous in temperate climates are never devoid of foliage in the inter-tropical regions; they flourish in full luxuriance throughout all seasons; their thick, broad, extended leaves, by inherent non-conducting power, proffer a cool umbrageous protection from the hot vertical rays of the sun.

The trees of high latitudes are not provided with their evergreen leaves thick, broad, and extended, but narrow, sharp, and close, admirably adapted to withstand the force of the northern blast, and to sustain the weight of the snow that it deposits upon them; thus their own non-conducting power, and that of their spotless burthen, can afford a thick and comparatively warm shelter for man and animals during the rigour of winter, a fact to be enlarged upon when the chemical phenomena of that season come under particular consideration.

Bounteous gifts are not scattered from the hand of Providence indiscriminately throughout the whole Creation, but are only abundantly presented in the localities most suited for the dwelling place and welfare of man; thus on mountain summits which are but seldom visited, and others which are perfectly inaccessible, no luxuriant trees are beheld, for at an altitude of sixteen thousand feet all vegetation ceases, save that of lowly moss and other cryptogamous plants which grow upon the verge of the mountain crown of everlasting snow.

The further consideration of the vital functions of plants upon the media necessary for their growth and perfection, will be presented in the ensuing season, and in proportion as we extend these researches, so shall we have cause to acknowledge with admiration, and appreciate with gratitude, the power and goodness of the Creator.

“He causeth the grass to grow for the cattle, and herb for the service of man; that he may bring forth food out of the earth.”

CHAPTER II.

Summer.

SUMMER arrives, the sun attains the zenith of its course, and under its ethereal influence the buds and blossoms of spring have transmuted into foliage and flowers; these diversify and adorn the scenery of the earth, captivate our senses by their exquisite structure and their delicious fragrance, and exert specific functions upon surrounding media, for maintaining the harmony and order of the Creation.

The seed weighed only a few grains when cast into the earth in spring; it has now produced a plant weighing many ounces, and the general increase of bulk which has ensued throughout the vegetable kingdom cannot fail to elicit a remark from the most listless observer; let us endeavour, if possible, to account for these phenomena upon chemical principles.

The ultimate analysis of the generality of vegetable products, as, for example, lignin, gum, starch, and sugar, educes from them nearly half their weight of oxygen and hydrogen, in the weights requisite for the constitution of water, and nearly half their weight of carbon; this fact

will be evident upon reference to the tabular statement at page 44.

The dry timber, woody fibre, or lignin, of an average sized oak, weighs about sixty tons, and in accordance with analysis it must contain about thirty tons of carbon: again, Europe alone, annually consumes about five hundred thousand tons of sugar, and this must contain about two hundred and fifty thousand tons of carbon.

Presented with these remarkable facts, it becomes a curious chemical question to determine the source of the enormous weight of the solid element carbon; for upon a close examination of the earth in which vegetables grow and flourish, it is discovered to lose no considerable weight, as the following account of an experiment will prove.

Two hundred pounds of earth were dried in an oven, and afterwards put into a large earthenware vessel, the earth was then moistened with rain-water, and a growing willow tree, weighing five pounds, was carefully planted therein: during the space of five years the earth was carefully watered with the purest water that could be obtained; the willow tree continued to grow and flourish; and to prevent the earth in which it was planted from being mixed with fresh earth, as dust blown upon it by the winds, it was covered with a metal plate, having numerous small perforations only suitable for the free admission of air.

After growing in the earth for five years, the willow tree was removed, and found to weigh one hundred and sixty-nine pounds, and three ounces; the leaves which fell from its branches every autumn were not included in this weight.

The earth was then removed from the vessel, again dried in the oven, and again weighed; it was discovered to have lost only about two ounces of its original weight; thus one hundred and sixty-four pounds and three ounces of lignin or woody fibre, bark, roots, &c., were certainly produced—from what source?

The chemist who made this remarkable experiment in

very early days of scientific investigation, reasonably concluded that the tree derived its increase of weight and structure from the water, as no other source was obvious; and the opinion that water was the sole aliment of vegetables, was long entertained by many of the greatest experimentalists; but knowledge regarding the powers and properties of matter became extended by indefatigable research, and the atmosphere was detected to be the source of the solid element carbon, and the water to be the source of the gaseous elements oxygen and hydrogen, of the one hundred and sixty-four pounds and three ounces of the lignin, bark, roots, &c., that caused the willow tree to increase in weight.

This statement regarding the source of the carbon, may at first appear incredible, but upon slight reflection, its truth will be admitted, because the atmosphere contains carbonic acid, and it is a compound of six parts by weight of carbon, and sixteen parts by weight of oxygen.

By means of several inorganic agents having most intense affinity for oxygen—the metals potassium and sodium for example—carbonic acid may be decomposed, and its carbon educed in a solid form; but it is discovered that the leaves of vegetables, whilst under the influence of vitality, have the power of effecting the decomposition of carbonic acid, with a degree of refinement and precision, perfectly inimitable by the highest scientific skill; in fact, they miraculously withdraw and secrete its carbon to confer solidity upon their own structures, and liberate its oxygen in a gaseous form to restore the balance of the atmosphere when vitiated by the results of respiration and combustion.

It has been experimentally proved, page 85, that carbonic acid is present in the atmosphere, yet the question will occur—is it there present in sufficient quantity for the supply of carbon, to constitute half the weight of trees, shrubs, plants, herbage, flowers, and the endless variety of vegetable productions?

Chemistry proves that the atmosphere naturally contains

as one of its essential constituents—absolutely necessary to the existence of the animated creation—abundance of carbonic acid for the supply of carbon to vegetables, its amount, as shown in the tabular statement at page 21, being equal to the enormous weight of five trillion, two hundred and eighty-seven billion, three hundred and five million of tons.

Or to place the extraordinary fact in a yet more remarkable point of view, the number for expressing the tons of carbonic acid naturally present in the atmosphere, vastly exceeds that of the human beings who have existed, and that of the seconds of time which have elapsed since the Creation to the commencement of the present year, the former being only one hundred and fifty billion; the latter only one hundred and eighty-four billion, six hundred and seventy-four million, eight hundred and sixteen thousand.

In addition to the enormous weight of carbonic acid naturally present, it must be remembered that the respiration of man and animals, the combustion of various kinds of fuel, the germination of seeds, the ripening and decay of fruits, the putrefaction of animal and vegetable matters, are constantly sending forth incalculable quantities of carbonic acid into the atmosphere; in fact, Chemistry can only determine with approximate accuracy the weight of the quantity of carbonic acid exhaled by human beings, and the result strikes the mind with amazement at the stupendous scale upon which natural phenomena proceed under the guidance of Omnipotence.

The volume of carbonic acid produced by the respiration of a healthy adult individual during twenty-four hours, amounts to about fifteen thousand cubic inches, containing about two thousand six hundred grains of carbon, or about six ounces.

Every hundred persons, therefore, produce a quantity of carbonic acid, containing between thirty-seven and thirty-eight pounds of carbon; so, assuming thirty-seven pounds as the average, one million of human beings would thus ex-

hale into the air during twenty-four hours, a quantity of carbonic acid, containing no less than three hundred and seventy thousand pounds, or upwards of one hundred and sixty-five tons of carbon.

The total population of the globe is estimated at seven hundred and sixty million, therefore, on the above data, it would exhale into the air, during twenty-four hours, a quantity of carbonic acid containing one hundred and twenty-five billion, four hundred million of tons of carbon.

"If there were not excellent and adequate adjustments which compensate for, and virtually remove this poisonous effluvium of carbonic acid—for such it is proved to be when in a concentrated state, or undue quantity—it would soon overwhelm us," and we have indeed occasion to extol the power and beneficence of the Almighty, when we discover the miraculous workings which He has ordained for the disposal and future utility of the agent we are considering.

In the first place, carbonic acid is a vapour, and this physical state although of considerable specific gravity, page 23, enables it from any of its sources ultimately to blend uniformly with the enormous volume of the atmosphere, and to elude detection in hurtful quantity; and "this carbonic acid which is poison to us, is the food of plants, and of the whole vegetable world; they absorb it into their systems, and whilst they retain the carbon, they emit the oxygen, and so feeding themselves they purify our atmosphere."

Chemistry thus reveals the mutual dependence of the animated kingdoms, and presents it for our fervent admiration and acknowledgment as a magnificent illustration of the power and goodness of Him "Who hath created nothing in vain, and Whose tender mercies are over all His works."

The miraculous process of the analysis or decomposition of carbonic acid by the vegetable kingdom, appears to be constantly active, though certainly in the highest degree under the direct influence of solar light, and it admits of most satisfactory illustration by simple experiments.

Provide a quart, wide-mouthed, stoppered bottle, remove the stopper and apply a slight touch of pomade to its ground part, and likewise to that of the neck of the bottle, replace the stopper, turn it round gently twice or thrice to distribute the pomade thinly and evenly between the ground surfaces to make them air tight; then again remove the stopper and pour a table-spoonful of water into the bottle.

Kindle a wax taper attached to a wire, as in a former experiment, introduce this into the bottle, and let it remain therein until the flame cease; then withdraw the extinguished taper, and quickly introduce—roots downwards—a sprig or two of mint just drawn from the ground; lastly, insert the stopper, tie it over with string that it may not be forced out by expansion of the aëriform contents of the bottle, which will ensue when it is exposed to full sunshine, page 80, and this must next be done.

The bottle originally contained atmospheric air; the elements of the wax taper—hydrogen and carbon—introduced therein, continued to burn by exerting their chemical affinity for the atmospheric oxygen, thus producing water and carbonic acid, and educing nitrogen, until the oxygen became nearly exhausted, when combustion could no longer proceed, being overwhelmed with its products and educt, which are now contained in the bottle, and are perfectly unfit for the maintenance of life or for the support of flame.

The introduction of the sprigs of mint, and the exposure of the bottle to full sunshine for several days, will effect a remarkable change in the nature of its aëriform contents: solar light will induce the leaves of mint to decompose the carbonic acid, to elaborate its carbon into their own structure, and to elicit its oxygen, which will blend with the nitrogen, and ultimately restore the atmosphere in the bot-



Fig. 21.

tle to its original condition ; in proof of which fact the stopper may be loosened and withdrawn, a lighted taper introduced, and its flame will burn with the same brilliancy and for the same time that it did when originally introduced to vitiate the air which the mint has now purified.

If a portion of air be vitiated by respiration, as in an experiment already performed and described, page 88 ; upon introducing a few sprigs of mint into the glass, and then exposing the arrangement to sunshine, the air will be restored to its original purity.

Sprigs of mint are directed to be used in these experiments, as they were the original simple means by which the important discovery was made at an early period of the science of Chemistry ; it was then found that air was not vitiated by the growth of a sprig of mint kept in it for some months ; it was therefore deemed probable that the process of vegetation might restore air when injured by burning candles.

Accordingly a sprig of mint was put into a portion of air in which a wax candle had burned, and in ten days afterwards it was found that another candle burned perfectly well therein ; and then afterwards, to verify the conclusion, the injured air was divided into two portions, the mint being put into one of these, the other remaining alone, and after the lapse of some days, it was always found that a candle would burn in the former but not in the latter.

This wonderful restoration of the air was found to depend upon the health and vegetating state of the plant, and though many fresh leaves of mint were placed in a small quantity of air vitiated by combustion, and changed repeatedly for many days, they failed to ameliorate the condition of the air.

The remarkable purificative action is not peculiar to growing mint, because it may be effected by balm, groundsel, spinach, and many other plants, so that it is not dependent upon any aromatic principles, but upon the decomposition

of the carbonic acid by the vegetable that may be selected for the experiment.

The experiments now detailed were originally made nearly eighty years since, when refined methods of operating were unknown, but recent researches upon the same important subject, conducted with accurate apparatus, fully corroborate the conclusions that were drawn by the original discoverer, and by whom they were stated in the following words:—

“These proofs of a restoration of air by plants in a state of vegetation, though in a confined and unnatural situation, cannot but render it highly probable that the injury which is continually done to the atmosphere by the respiration of such a number of animals and the putrefaction of such masses of both animal and vegetable matter, is in part, at least, repaired by the vegetable creation; and notwithstanding the prodigious mass of air that is corrupted daily by the above-mentioned causes, yet if we consider the immense profusion of vegetables upon the face of the earth, growing in places suited to their nature, and consequently at full liberty to exert all their powers, both inhaling and exhaling, it can hardly be thought but that it may be a sufficient counterbalance to it, and that the remedy is adequate to the evil.”

Vegetation will not proceed in a mixture of oxygen and nitrogen, because there is no compound of carbon present in them to yield solid matter, and even when oxygen and nitrogen are mingled in the proportions as pointed out by analysis to be those in which they constitute the chief volume of the atmosphere, page 92, the addition of eight or ten per cent. of carbonic acid will form a medium fatal to plants when in the shade, but not when exposed to solar light.

The proportion of carbonic acid naturally present in the air is most unquestionably essential for the welfare of animal life, although the manner in which its influence is exerted

remains a mystery hitherto unsolved by the science of Chemistry.

Experiments similar in principle to those now detailed, but conducted with the greatest precision, lead to the important conclusion that the vegetable kingdom though a silent, is an unceasing agent in sustaining the uniform balance of the constituents of the atmosphere, and in contributing its share to the maintenance of the regularity and beauty of the works of the Creator.

The president of a scientific society which the discoverer of the foregoing phenomena ornamented, addressed him concerning them in the following eloquent terms:—

“From these discoveries we are assured that no vegetable grows in vain, but that from the oak of the forest to the grass of the field every individual plant is serviceable to mankind, if not always distinguished by some private virtue, yet making a part of the whole which cleanses and purifies the atmosphere.

“In this the fragrant rose and deadly nightshade co-operate; nor is the herbage nor the woods that flourish in the most remote and unpeopled regions unprofitable to us, nor we to them, considering how constantly the winds convey to them our vitiated air for our relief and their nourishment. And if ever these salutary gales rise to storms and hurricanes, let us still trace and revere the ways of a beneficent Being, who not fortuitously, but with design, not in wrath, but in mercy, thus shakes the water and the air together, to bury in the deep those putrid and pestilential effluvia which the vegetables on the face of the earth had been insufficient to consume.”

Carbonic acid may be educed from the atmosphere by the employment of the agents and apparatus that are next to be described. Provide a narrow-mouthed stoppered half pint bottle of flint, or green glass, filled with commercial hydrochloric acid, which is an aqueous solution of the vapour of the acid, page 33; select a lump of clean dry chalk, about

the size of a small orange, break two small pieces from it about the size of hazel nuts; throw one of these pieces into a wine-glass containing a tea-spoonful of hydrochloric acid diluted with an equal quantity of water; remark the commotion, foam, or effervescence that will ensue instantly, continue for a few minutes and then cease. This phenomenon admits of the following explanation:—

The proximate elements of chalk or carbonate of lime 50, are carbonic acid 22 + lime 28; and of hydrochloric acid 37, hydrogen 1 + chlorine 36; the ultimate elements of lime 28 are oxygen 8 + calcium 20, the latter combines with chlorine 36, and produces chloride of calcium 56, it dissolves in the water of the diluted acid, and also in 9 produced by the combination of oxygen 8 with hydrogen 1, whilst the carbonic acid 22, being released from combination, escapes in its vaporous form and produces the effervescence.

Take the other small piece of chalk, place it in the bowl of a clay tobacco pipe, thrust this into a fire that it may be made red hot for about half an hour, then remove it from the fire, and shake the white lump from the bowl of the pipe into a saucer; let it become cold, then pour thereon a tea spoonful of water, it will become hot, and emit steam, whilst the lump will gradually unfold, and crumble into an apparently dry powder; throw this into a wine-glass containing diluted hydrochloric acid, as in the first experiment, remark that no effervescence will ensue, and for the following reason:—

The imponderable agency of heat decomposed carbonate of lime 50, or, in other words, excited repulsion to ensue between its proximate elements, carbonic acid 22 + lime 28; the former arising as a volatile vapour, mingled with the smoke and heated air ascending from the burning fuel, and was dissipated, but the lime being a fixed solid remained. When water was poured thereon, the vehement affinity of the

lime for it, caused a definite portion to become solid, and in such new state, the latent heat which had preserved it in a liquid state, being no longer needed, became sensible, or was expelled at such an intense degree, as to convert an extraneous portion of water into the state of vapour or steam; the resulting white powder is anhydrous lime 37, containing solid water 9 + solid lime 28.

When such anhydrous lime 37 was placed in diluted hydrochloric acid 37, both substances were decomposed; chlorine 36, combined with calcium 20, to produce chloride of calcium 56; whilst hydrogen 1, combined with oxygen 8, and produced water 9, which, mingling with the now liquified water of the previously enhydrated lime, and that of the dilution, caused the solution of the newly formed chloride of calcium; the whole actions took place quietly, because no carbonic acid was present to cause an effervescence.

These changes being understood, place the large lump of chalk, from whence the two small pieces were broken, in one pan of a pair of scales, and then in the other pour lead-shot, and sand sufficient to effect an equilibrium, leave the counterpoise of the chalk, but remove this from its pan into a clean iron ladle, just sufficiently large to contain it; then take another ladle of the same size, invert its brim over that of the first, place a strip of wood across the two handles, and bind them firmly to it with wire or string, that the chalk may be safely inclosed between the two bowls; thrust them into a clear fire, heap a few pieces of charcoal over them, and let the arrangement be made bright red hot, and by replenishing the fuel, continue so for two hours: then withdraw it from the heat, let it become cold, carefully unbind the handles, remove the white solid lump, and every particle of white dust, into the scale-pan from whence it was taken; remark that it will not restore the equilibrium, and that its original counterpoise

will preponderate: gradually remove globules of shot and grains of sand from this, and set them carefully aside in a small glass until a balance be effected.

The whole quantity of the shot and sand was the weight of the original chalk, the remaining portion is the weight of the lime educed, and the portion removed is the weight of the carbonic acid expelled by the action of the heat.

These weights might be determined in standard grains and a delicate balance; but such refined and costly apparatus cannot, generally speaking, be conveniently procured, and as the present object is not absolute, but approximate accuracy, the common cheap arrangement is sufficient for its fulfilment. An experienced chemist would obtain the following result:—a mass of carbonate of lime weighing two ounces, or 960 grains, exposed to heat would lose 422·4 grains of carbonic acid, and leave 537·6 grains of lime.

Put a tea-spoonful of powdered turmeric root into a two-ounce vial, fill it with alcohol, cork it, shake it for a few minutes, then let it rest until a considerable sediment falls to the bottom, and leave a very dark orange coloured liquid or tincture above; pour this carefully from the sediment or precipitate into a shallow earthenware plate; next draw through it a piece of white blotting-paper about the size of this page, that it may be stained of a bright yellow colour; lastly, hang it over a string to dry, return the remaining tincture to the vial, and preserve it for the formation of more "turmeric paper," technically so called, at any future time that it may be required.

Obtain a large wide shallow earthenware cream pan—as used in a dairy—place the whole of the lime in its centre, pour water thereon to render it anhydrous or slaked; this being effected, continue to pour water until it rise to within an inch of the brim of the pan, carry this to a table either within or without doors, if the latter, it must be sheltered from rain.

Then, with a clean wooden ladle, stir the lime and the water together until the whole become uniformly milk white; it is technically called "milk of lime," and consists of lime partly in chemical solution and partly in mechanical diffusion throughout the water; take care that none spill over the pan, and that little or none be removed by the ladle; this, after use, must always be placed in a clean dish set beside the pan.

Cut a strip from the turmeric paper, about the length and width of the margin of this page, dip about an inch of one of its ends into the milk of lime for a moment, the yellow colour of the paper will be rendered brown: this effect upon the vegetable colour is characteristic of alkaline substances, it will ensue with potassa, soda, and ammonia; therefore lime is called an alkaline earth, and the turmeric paper, a test of alkaline substances generally.

After the milk of lime has become still, a portion of lime will precipitate, and leave the upper contents comparatively clear; watch this liquid surface, and remark that it will gradually become covered with an iridescent film, which will gradually become an opaque white crust; this when stirred with the ladle will sink or precipitate, and leave a comparatively clear surface, but this will again present an iridescent film and white crust; these facts being ascertained, stir the whole of the milk of lime every two or three hours, daily, until neither film nor crust appear, dip the end of a slip of the turmeric paper into the now clear transparent liquid; the yellow colour will only be wetted, as by plain water, and not changed to brown.

The explanation of the whole phenomena of the proceeding may be presented in the following terms:—upon the first exposure of the milk of lime to the atmosphere, the lime exerted chemical affinity for its carbonic acid, and produced carbonate of lime, a film so peculiarly crystalline, thin, and transparent, as to be incapable of reflecting white light, but capable of refracting it into the seven primitive

colours, page 52 ; which then caused the iridescent appearance ; gradually, however, the lime attracted more carbonic acid, and as a consequence, the mechanical or physical structure of the film became thick and opaque, and capable of reflecting white light—like chalk or marble—then, being of greater specific gravity than the remaining liquid, sank or precipitated through it when stirred, whilst the newly exposed surface of the latter in its turn became carbonated, and presented similar phenomena. Subsequently, by stirring the whole of the milk of lime, the mechanically diffused lime was brought into action, in addition to that chemically dissolved, so that, both being presented to the atmosphere, the formation of carbonate of lime was expedited, and ultimately completed, the whole of it precipitated to the bottom of the pan, and left only plain water, of course devoid of any alkaline property, and therefore incapable of affecting the colour of the turmeric paper.

The next proceeding will be to raise the pan gently into such a position that its lip or spout may be inclined over a bucket, into which the plain clear water may steadily flow ; in doing this, a portion of the carbonate of lime will slowly glide along the bottom of the pan in the direction of the flowing water, but hitherto will not become diffused ; the moment, however, diffusion ensues, the pouring off or decantation of the water must be stopped ; the contents of the pan shaken, and the milk of chalk, poured into an earthenware soup-plate, and the pan, dish, and ladle, washed with a small portion of water from the bucket, to free them from all adhering carbonate of lime, which must all be added to that in the soup-plate ; lastly, set this in a warm oven, leave its door partly open that the steam which will arise from the water may readily escape, and at length leave the carbonate of lime perfectly dry.

Collect all this carefully by means of a tea-spoon, and brushing with a stiff feather, place it in one scale pan, and the whole of the original counterpoise in the other, and dis-

cover that it will approximate the original equilibrium, in consequence of the lime having exerted chemical affinity for the carbonic acid of the atmosphere, and thus become carbonate of lime, having exactly the same composition, and nearly the same weight as the original lump of chalk; indeed with refined apparatus, employed by a practised experimenter, it would have exactly the weight, and although with rude contrivances in unpractised hands, the mechanical property of original weight may be mutable, the chemical property of original composition is immutable.

For the continuation of this curious investigation regarding the carbonic acid present in the atmosphere, some additional apparatus and agents will be required; in the first place, a clean dry flask, to which adapt a cork having a notch about the sixteenth of an inch deep and wide, cut down its side from one end to the other: then remove the cork and set the flask to stand on a ring; in the second place, a clean dry narrow-mouthed pint bottle of flint or green glass, to which adapt a sound cork, then remove it and perforate it in the direction of its length with a large bradawl, enlarge this perforation with a fine round rasp until it will admit the wooden plug attached to one end of a flexible tube about a quarter of an inch in diameter, and fifteen or eighteen inches in length, which is commonly known to smokers as "a snake," and has a mouth-piece at its other end; lastly, a wide-mouthed stoppered half-ounce vial, containing five or six globules of potassium, about the size of peas, and a portion of a liquid called naphtha, from the Persian *nafata*, to exude or to pour out, as this liquid naturally does from the soil of the shores of the Caspian sea, it is chemically a hydro-carbon, as it simply consists of hydrogen and carbon, and is used for preventing potassium, sodium, and other substances from oxidation.

Place the whole of the carbonate of lime in the pint bottle, add to it two table-spoonfuls of water; introduce a lighted taper for a moment, its flame will not be affected, withdraw

it and introduce it within the flask for a moment, its flame will not be affected, and thus prove both vessels to contain atmospheric air.

Introduce the mouth-piece end of the flexible tube, within the mouth of the flask, and let it pass gently down the neck to rest on the bottom of the bulb of the flask; pour two table-spoonfuls of hydrochloric acid into the pint bottle, remark the effervescence that ensues, introduce the lighted taper, its flame will be perfectly extinguished, remove it, and quickly fit the cork at the other end of the flexible tube to the mouth of the half pint bottle, thus leave it until the effervescence cease.

Remove the cork gently, pour in a similar quantity of hydrochloric acid, again insert the cork, and so on, from time to time, until the effervescence become materially subdued, but before it entirely cease, remove the mouth-piece end of the flexible tube from the flask, insert its notched cork, and dip the mouth-piece into a wine-glass filled with clear lime-water; bubbles will issue from the mouth-piece, the lime-water will become milk white, and then ultimately resume its original clearness.

In accordance with the double decomposition of carbonate of lime and hydrochloric acid so fully detailed at page 131, carbonic acid is educed from the carbonate of lime contained in the pint bottle, therefore expels the common air that it originally held, takes its place, and, being incapable of supporting ordinary combustion, extinguishes that of the taper; upon the insertion of the cork, the carbonic acid as educed, passing through the flexible tube, and being of greater specific gravity than the atmosphere, flows from the mouth-piece, and displaces the air that the flask contained,—precisely as it would have been displaced by water, or other liquid—and therefore fills the flask; the fact may be proved by removing the notched cork, and introducing the lighted taper; its flame will be extinguished, as it was in the pint bottle; remove the taper and replace the cork.

When the mouth-piece of the flexible tube was dipped into the lime-water contained in the wine-glass, the carbonic acid issuing forth, and bubbling through, at first rendered the clear liquid milky, on account of combining with the lime that was dissolved by the water, and producing carbonate of lime, which is undissolved by the water, until it be impregnated with an excess of carbonic acid, page 40, and then the liquid resumed its original clearness, but will again become milky if it be left for a day or two exposed to warm air, in consequence of the precipitation of the actual carbonate of lime, by the volatilization of the excess of the carbonic acid.

Be it remembered, or experimentally proved, that pure quick lime, slaked lime, milk of lime, or lime-water, when treated with hydrochloric acid, will afford no such phenomena; these have ensued during the foregoing experiments, exclusively on account of the carbonic acid which the lime abstracted from the atmosphere, and that such carbonic acid does actually contain carbon as one of its elements, may be proved by the next and concluding experiment.

With a pointed wire, remove a globule of potassium from the vial, place it on a slip of turmeric paper, the yellow colour will remain unchanged; divide the globule with a pen-knife; the lustre of the metal will appear, return one half to the vial, place the other with its newly cut surface upon the turmeric paper, leave it for a few minutes, and the yellow colour in contact with that surface will be changed to brown; because a portion of the metal has exerted affinity for the oxygen of the air, has combined with it and produced oxide of potassium or potassa, which is an alkaline substance; return this half of the partially oxidized metal to the vial, from whence remove the other, stand at arm's length, and throw it into a tumblerful of water, the metal will not sink, it will float—because its specific gravity is less than that of water, page 27; and will instantly burst into a vivid purple flame, and after moving about rapidly for

a few seconds, will vanish, and leave the water perfectly clear, but capable of changing the yellow colour of the paper to brown. Because water 9 consists of hydrogen 1 + oxygen 8: potassium 40, has intense affinity for the latter; it actually decomposes the water to obtain its equivalent of that element 8, and produce oxide of potassium or potassa 48, which dissolves in the remaining undecomposed water, forming an alkaline solution as detected by the turmeric paper; the hydrogen 1, of the water 9 that is expelled during this vehement affinity of the metal for the oxygen 8 is so intensely heated, that it kindles, and with a minute portion of the vapour of the potassium, burns with the vivid purple flame, and reproduces vapour of water 9.

Having thus proved the powerful affinity of potassium for the oxygen contained in air and water, the metal may next be employed to exert affinity for the oxygen contained in carbonic acid, and to educe its elementary carbon.

Remove two globules of potassium from the vial, to the surface of a piece of white blotting paper, press them gently, that it may absorb their adherent naphtha, then remove the cork from the flask, drop the globules therein, and again insert the cork; hold the neck of the flask, lift it that its bulb may be held over the flame of a spirit-lamp, at the distance of two or three inches; move it round and round, that it may be gradually warmed; bring it nearer and nearer, until the flame touch the part of its bulb next the potassium, hold it there steadily, the metal will melt, and then burn with a vivid purple light; when the combustion cease, set the flask to stand upon a ring to cool.

Remove the cork, introduce the lighted taper, its flame will not be extinguished; examine the bulb of the flask at the part where the potassium was heated; a black substance, incrustated with a white substance, will be discovered; these phenomena admit of the following explanation.

Had the flask been tightly corked, it would have burst by the expansion of its included carbonic acid, when heated

over the flame of the lamp, but the notch in the cork permitted a small volume to escape; instantly after this, the melted potassium exerted its intense affinity for the whole of the oxygen of the yet remaining and large volume of the carbonic acid, and as it burned therewith, atmospheric air, in a proportionate volume, entered through the notch of the cork, to fill the flask, so that the flame of the taper can burn therein.

Moreover, carbonic acid 22, consists of carbon 6+oxygen 16, and the equivalent of potassium is 40, so, during the combustion, potassium $40 \times 2 = 80$, combines with oxygen $8 \times 2 = 16$, and oxide of potassium or potassa $48 \times 2 = 96$ is produced, whilst carbon 6 is educed; the product is white, the educt is black.

Pour a tea-spoonful of water into the flask, shake it for a few seconds, the potassa will dissolve, the carbon will diffuse; pour all from the flask into a white saucer, dip therein a slip of tumeric paper, its yellow colour will change to brown, by the action of the alkali, whilst, through its solution the carbon will precipitate; carbon, be it remembered, that was originally present in atmospheric air, and that has been actually educed therefrom during the foregoing experiments.

Such are a few, and a few only, of the extraordinary phenomena presented by the atmosphere and its elements, which admit of elucidation by experiments demanding but moderate care and skill for their performance; others will be presented as our inquiry proceeds, and will amply reward the young student of the delightful science of Chemistry, by unfolding hidden treasures whose ceaseless changes are of the utmost interest and importance in maintaining that sweet harmony of Nature which the philosophic mind so ardently admires and so eagerly explores.

The pleasure derived from the application of chemical experiments to the elucidation of the nature and habitudes of the various forms of matter presented throughout the

Creation, with the view of interpreting many wonderful phenomena, is unceasing, and so varied that it never satiates the sense, at the same time "it is far removed from the low gratifications of sense in another respect; while those hurt the health, debase the understanding, and corrupt the feelings, this elevates and refines our nature;" teaching us, whilst contemplating the wonders by which we are surrounded, and which are so essential for our welfare, to acknowledge the Omnipotent Hand by which they were created, and are perpetually governed.

Advantage may be taken during the zenith of summer for the performance of several simple, yet instructive experiments, regarding the expansion of solids, liquids, and gases by heat, and therefore a few directions for the construction of the requisite apparatus will be next presented.

First, as regards solids, and of these forms of matter the metals are the most expansile by heat; provide a truly cylindrical bar of iron, or copper, about one inch in diameter, and four inches in length, with a piece of stout iron wire screwed into one of its ends, and fitted to a wooden handle; likewise a piece of iron plate, about an eighth of an inch in thickness, and three inches square, having in its centre a circular aperture that will most exactly fit, or, technically gauge the cylindrical bar, when in a cold room or cellar; there leave the gauge, but carry the bar into the hottest sunshine, place it upon the top of a black hat, and leave it for about an hour.

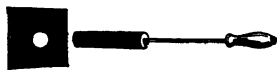


Fig. 22.

Bring the gauge quickly from its cool situation, hold the bar by its wooden handle, and endeavour to make it pass into the gauge, it will be found impossible to do so, because the bar is expanded by the heat of the sun: take it and the gauge back to the cool situation, and when they become of the same temperature, the bar will be found to

enter the gauge with the same facility that it did originally, because the bar by cooling has contracted to its original dimensions.

If the bar be heated by immersion in boiling water, or exposure on a fire for a few minutes, whilst the gauge be kept cold, the expansion will more quickly ensue, and to a more considerable extent than it did by exposure to solar heat.

On the other hand, if the bar be kept cold, and the gauge exposed to solar or artificial heat, it will expand, and readily allow the bar to enter; but in both cases, the change of dimensions sustained by either piece of metal is merely mechanical and temporary, not chemical and permanent; and in the language of science, metals are said to expand

by elevation, and to contract by depression of temperature; this is also the case with liquids, as may be experimentally illustrated by making the arrangement which is represented in the accompanying engraving, and although it may appear a simple contrivance, it requires some care in its construction.



Fig. 23.

In the first place, a flask must be chosen having a thin bulb and thick neck; then a sound cork that will barely enter the mouth of the flask must be placed under a flat board, and rolled upon a table until it become soft and pliable, and can be thrust into the mouth of the flask without difficulty.

Remove the cork, perforate it in the direction of its length with a large bradawl, then enlarge this perforation with a fine circular rasp, until it will closely and accurately fit the circumference of one end of a glass tube about a quarter of an inch in diameter, and from twelve to fifteen inches in length; this should be held in a folded cloth, lest

it break; it must not be twisted into the perforation, it must be held steadily, and the perforation twisted on to it until its end just protrude from the lower end of the cork.

Fill the flask to its brim with alcohol, tinged red with cochineal, and then carefully and accurately insert the cork, a portion of the alcohol will immediately rise in the glass tube; if any escape from the mouth of the flask, and dribble on the bulb, it must be wiped away; lastly, paste a strip of white paper on the whole length of the glass tube, or it may be thrust into the upper and lower notches made in a long slip of white card, so that by either contrivance the height of the coloured alcohol may be rendered readily visible.

Thus prepared in a cool room, carry the apparatus into the sunshine, place it to stand on a ring, as at page 139, and as the alcohol becomes heated it will expand and rise to a considerable height in the glass tube; but, upon removing the apparatus to the cool room in which it was constructed, the alcohol will part with the heat that it had absorbed from the sunbeams, and will contract and ultimately fall in the tube to its original level.

Upon this principle the thermometer is constructed; it consists of a narrow glass tube, with a small bulb blown at one extremity, sufficient mercury is then introduced to fill the bulb and a part of the tube or stem, the air is next completely expelled from the remainder of the stem, and its open extremity securely closed by melting the surrounding glass.

The instrument thus prepared, upon being heated, the mercury will expand and ascend to a certain height in the stem, and upon being cooled will contract and descend to its original level, so that it becomes to a certain extent a measure of heat, and by attaching it to a slip of wood or ivory, upon which marks can be made, it becomes more serviceable in this respect.

The marks are called degrees, and the slip of wood, ivory,

or other substance upon which they are made is called a scale of degrees, these are of arbitrary magnitude, between two extremes, one being near the lower, and the other near the upper part of the scale, and distinguished as the freezing point and the boiling point of water.

The scale of degrees which is commonly known and employed in England, is that of its inventor Fahrenheit; the freezing point being marked 32° , and the boiling point 212° , the scale between these two extremes being divided into 180° ; but on the continent the scale of degrees which is employed, is that of its inventor Celsius, and usually distinguished as the centigrade, on account of the scale being divided or graduated to 100° between the freezing point and the boiling point, the former is then indicated by 0° , and the latter by 100° ; the thermometric degrees that are mentioned in these pages, are those of Fahrenheit's scale; and when the mercury stands at 62° of such scale, page 23, it is considered to indicate that the atmosphere is at its mean or standard temperature.

The barometer is a perfectly distinct instrument, and only indicates the weight of the atmosphere at any given time of observation, it is constructed on the principle of the contrivance mentioned at page 22, by which the total weight of the atmosphere was discovered.

The barometer consists of a glass tube, about an eighth of an inch in thickness, half an inch in the bore or calibre, and thirty-two inches in length, closed at one end; this tube is filled with mercury, and then inverted with its open end into a small cistern also containing mercury; this being done, and the tube set upright and fastened with loops to a wooden support or back, having a scale of inches, and their decimal subdivisions at its upper part, the mercury is observed to fall for the space of two or three inches, and leave the upper part of the tube empty.

The mercury falls because the surrounding atmosphere is unable to balance a greater height or column of the heavy

metal, and if the mercury that remains in the tube could be removed and accurately weighed, the result would present the weight of a column of the atmosphere of equal diameter with that of the bore of the tube.

The mercurial column and the aërial column balance each other, if the latter fluctuate in weight, the former will in height; because there is no air in the tube above the mercury to impede its movements. The tube is made thirty-two inches long, that there may be space for the ascent of the mercury when urged upward by the external pressure of the air upon that in the cistern; if it were only thirty inches long there would be no empty space during many states of the atmosphere, because it would be enabled at its mean pressure to balance or support a column of mercury thirty inches high, page 22, and the tube would remain full until the pressure of the atmosphere diminished, and then the mercury would fall to a certain equivalent extent.

Although the expansion of air by heat and its contraction by cold have been illustrated at page 80, the important fact can be farther exemplified by the employment of an apparatus, the form of which is shown in the accompanying engraving.



Fig. 24.

This apparatus, like the preceding, page 142, requires care in its construction, the flask must be chosen with a thin bulb and a thick neck, the cork selected, softened, perforated, and fitted on to the glass tube with the preceding precautions, and lastly, the cork inserted into the mouth of the flask, containing a portion of coloured alcohol, to include the air above its surface. A very simple test will detect if the apparatus be air-tight—viz., place the upper and open end of the glass tube between the lips, and endeavour to force air down it; if this can be done easily, and if plenty of air-bubbles appear through the alcohol, the appa-

ratus is leaky and useless ; if, on the other hand, it can only be done with difficulty, and but few air-bubbles appear, and especially, if upon removing the lips from the tube, a portion of the coloured alcohol rise in it and remain stationary at a considerable height above the level of that in the flask, when held by its neck, the apparatus is air-tight, and fit for use, and the tube may be fitted with a slip of white paper or card as already directed.

Should the apparatus prove leaky on the first trial, or should the coloured alcohol fall quickly in the tube after the second trial ; the whole of the upper part of the cork, the part of the tube that it surrounds, and the neck, into which it is inserted, must be covered with a solution of caoutchouc, gutta percha, or strong glue, to close all pores or fissures, and when either of these cements have become hardened, the apparatus may be tested by endeavouring to force in air from the lips, and then if the coloured alcohol rise and remain stationary in the tube, whilst the flask is held by its neck, all things are favourable for the success of the experiment on the expansion of air by heat and its contraction by cold.

Carry this apparatus into the sunshine, place it on a ring as already directed, the heat will cause the air within the flask to expand, it will press upon the surface of the alcohol and cause its ascent to a very considerable height in the tube ; remove the apparatus to the cool room in which it was constructed, the air will part with its absorbed heat, contract, relieve the alcohol from pressure, and it will ultimately fall to its original level.

Atmospheric air, all aëriform substances, gases, and vapours undergo similar expansions and contractions when exposed to similar elevations and depressions of temperature, but liquids and solids have each their specific expansions and contractions when so treated, some expanding and contracting more than others, and no two of them

precisely agreeing in these remarkable and important properties.

The examination of the chemical phenomena presented by the vegetable kingdom may be now resumed; these will afford much interesting and important information.

The imponderable agency of solar light, although not required in the early stages of germination, becomes of the greatest importance to the welfare of the growing plant at a more advanced season.

For example: take a flourishing plant with leaves full verdant, supply it with a due share of heat, air, and water, but keep it in darkness for a few days, then withdraw it for inspection, its leaves will not be found vigorous and green, but languid and pale; because the access of light was prevented, and the vessels of the plant could not elaborate those principles from the earth, water, and air which are essential to its welfare, the stem becomes weak, soft, and long: the physical structure of the leaves is likewise deranged, and they are not capable of reflecting a proper amount of the green rays of light; but expose the languid pale plant to the sunlight for a few hours, and its vital functions will be excited into proper action, it will regain both health and power of reflecting its proper colour.

The generality of plants have a predilection for solar light, and if they be placed either intentionally or accidentally in gloom, through which may penetrate but a single ray, they will turn and bend their branches and leaves towards the spot upon which its effulgence falls, as if eager to exchange their pallor and languor for colour and health.

Solar light excites strange chemical affinities amongst the elements of plants, which are by no means clearly understood; thus some leaves are acid in the morning, tasteless at noon, and bitter at night; some flowers are white or blue, according to the intensity of the light; many fruits are more acid in

the morning than in the evening, some flowers expand their petals to the sunshine, others close them against its power.

The influence of solar light in promoting the colour and ripening of fruits is also remarkable; select a peach for example: the portion of it which is fully exposed to light, reflects a brilliant crimson, whilst that in shadow, reflects pale green and yellow; the taste of the one part is more luscious than the other, because the direct action of light has there stimulated the elaboration of the most sugar; hence also the sweetest fruits are generally found in southern climates.

On the other hand, some plants when grown in the full glow of light, become unfit for food; this is the case with celery, it grows green, and bitter; but by banking earth around its stem to exclude the light, it becomes blanched, and pleasantly aromatic to the taste, with the exception of the few leaves just above the earth, and these remain dark green and hurtful.

During the growth of lettuces they are tied around, that the exterior leaves may exclude light from the interior leaves, these become white and edible, and do not contain a poisonous principle which is discoverable in the dark green leaves; plants of endive and secale are grown under earthen covers to exclude the light, and thus become blanched and fit for food.

The shoots of a potato produced in darkness are white, straggling, and differently formed from those which the vegetable exhibits under the usual circumstances of its growth; the seeds of mustard and cress, germinating in darkness, put forth crops of a dingy yellow colour instead of a brilliant green: a plot of green grass, perfectly excluded from the light by a board or a stone, becomes of a pale yellow colour, and is soon killed, and even when partially excluded from light by the dense summer foliage

of surrounding trees and shrubs, it suffers a similar change of colour, and ultimately dies.

When a plant is placed in an extremely strong light, or exposed daily to the full glare of the sun, the solid matter is often elaborated with such rapidity as to check the growth by not permitting the various parts to expand properly, the plant is stunted, the leaves are small, and the stem thorny or hairy; this may be observed in those plants which grow on heaths, commons, or high hills.

The effects of the presence and absence of light upon the animal creation are no less remarkable; beasts and birds of tropical climates have generally brighter skins, and more vivid plumage, than those of climates farther distant from the equator, and a difference is even observable in the same climates between such as bask and fly in sunshine, and such as prowl and mope in darkness.

Solar light is absolutely essential to the health of man; a strong contrast is presented between the athletic stature and the ruddy cheeks of him who roves on the mountain, and the stunted form and the pallid features of him who crawls in the mine.

In the one case by the presence of light, conjoined with air, food, and exercise, chemical affinities are promoted between the elements of the animal secretions, to elaborate principles conducive to the healthy action of the vital functions, whilst in the other, by the absence of such stimulants in due proportions, these all become deranged, and disease results.

The vigorous mountaineer, if immured in a dark dungeon, though abundantly supplied with food, will soon become more pallid and unhealthy than the miner, who during the intervals of his subterranean toil, can have an opportunity of ascending for a few hours to enjoy the light of day.

"Truly the light is sweet, and a pleasant thing it is to behold the sun."

The poor inhabitants of gloomy and crowded districts

invariably have blanched and haggard features ; on account of the absence of free sunlight and fresh air, and—with sorrow be it spoken—their inability to procure a moderate share of wholesome food.

Solar light, by stimulating the exquisite structure of the eye to the sense of vision, manifests its universal importance, and illustrates the omnipotence of its Creator, who in the beginning said, "Let there be light; and there was light. And God saw the light that it was good."

It has been ascertained that "vegetables in general are extremely susceptible of impurities in the air that surrounds them, and very slight modifications in the proportions of its constituents are more, or less prejudicial to their growth, especially when they are prevented from the access of light."

In the free and open atmosphere of the country, with few exceptions, no matters hurtful to vegetation can be detected ; but the air of large cities and towns is subject to many local contaminations, arising from several causes, such as the combustion of coal, the smoke of furnaces, the gases and vapours educed or produced during metallurgical operations and other processes of the chemical arts and manufactures ; add to them the gaseous and vaporous emanations from decomposing organic offal in imperfectly constructed sewers, &c., and all these materially affect the health of the more delicately constituted vegetables, and also to a considerable extent that of the hardy tribes.

In the immediate vicinity of chemical manufactories, where enormous quantities of poisonous emanations are hourly sent forth into the atmosphere, the vital functions of vegetables are strangely deranged or altogether destroyed ; the grass, for example, is stunted and browned, the trees are leafless and withered, nor need we wonder at organic structures being thus affected, when the stone and iron of adjacent buildings are found decayed and corroded by the same agents.

The vapour of hydrochloric acid is found to be especially

fatal to vegetation ; it is most abundantly produced, and thrown into the air by some extensive operations of the chemical arts, and it causes sterility in their immediate neighbourhood ; its withering influence upon a plant may be illustrated as follows :—



Fig. 25.

Select a small healthy geranium or myrtle, growing in a flower-pot, tie the stem to a bright iron wire stuck into the mould, as a flower stick, set the flower-pot to stand in a saucer, placed in the centre of a large dinner-plate, containing about a fluid ounce of commercial-hydrochloric acid, then cover the arrangement with a bell-glass, the rim of which is to rest upon that of the plate.

Commercial hydrochloric acid contains the vapour of the acid dissolved in water, from whence however it will readily escape upon exposure to the atmosphere ; thus in the act of pouring the liquid into the plate a dense white fume will be observed ; this will continue to rise and contaminate the air contained in the bell-glass, and to manifest its poisonous effect upon the plant in the course of a very short time, by causing its leaves to droop and shrivel, and its corrosive power upon the iron wire by destroying the brightness of the metallic surface.

Upon removing the plant from this deleterious atmosphere, and attempting its restoration to health, all will be in vain, it is killed, and so would an animal be killed if subjected to a similar medium ; but the experiment would be wanton cruelty, as the fact is unquestionably established.

The colours of flowers are curiously affected by acid vapours, as may be proved in the following manner :—place a red rose in the centre of a bunch of dark purple pansies, sufficiently large for their stems to fill the neck of the glass that was employed in the experiment for illus-

trating the effect of respiration upon the air, page 82 ;



Fig. 26.

when introduced in an inverted position, so that the flowers may hang within the glass with their petals downwards : place a fragment of sulphur, about the size of a hazelnut, upon the bottom of an egg-cup, inverted and standing in the centre of a dinner-plate ; kindle the sulphur by touching it with a glowing coal, then place the glass containing the flowers to cover the flame, and to rest upon the plate.

The sulphur will continue to burn with a pale blue flame for a few minutes, on account of its affinity for the oxygen of the confined air, with which it unites and produces sulphurous acid vapour, page 38 ; this will ascend in the glass, and upon surrounding the bunch of flowers it will bleach the red rose and the purple pansies.

In the autumn a bunch of dahlias, of many colours, may be exposed to the vapour of sulphurous acid, and it will either blanch or modify them in a very remarkable manner.

In consequence of the existence of the above acid and other vapours in the atmosphere of cities, many plants



Fig. 27.

cannot be grown when fully exposed to its influence, and therefore the following arrangement has been successfully adopted to prevent them from sustaining injury in such localities.

The arrangement consists of a circular wooden box about fifteen inches in diameter and six inches deep, lined with sheet-lead or sheet-zinc to form a water-tight cistern : a stratum about two inches thick, of clean gravel stones, is placed upon the bottom of the lining,

then another stratum, about two inches thick, of turfy loam, is placed upon the gravel, and the remaining space is filled with loam, well moistened; in this various small plants and flower-roots are planted in the usual manner, and then covered with a large glass shade, the rim of which is to rest upon that of the box.

The arrangement of the earthy materials in the box closely resembles that of a natural soil, the water being partly retained in the upper strata by capillary attraction, and the excess percolating and accumulating amongst the lower stratum of gravel.

The air contained in the glass shade incites a portion of the water on the upper surface of the soil to change into vapour, and thus to saturate its whole volume with humidity; part of this condenses as drops upon the interior of the glass shade, and these trickle down again to the soil, again to rise in vapour, and again to condense and descend: by this incessant circulation the plants are never subjected to irregular watering, at the same time they are preserved from cold, dust, soot, smoke and noxious vapours, and accordingly continue to flourish in full perfection and beauty.

The rim of the glass shade merely rests upon that of the box, and is not air-tight, so that during changes of temperature the included volume of air undergoes expansions and contractions which enable it to become renewed from the external atmosphere; but experiments have been made with glass shades fitting perfectly close, and even then the plants flourished for a time.

It was likewise discovered that the volume of air thus effectually confined and prevented from renewal, after a short exposure to sunlight, contained a considerably greater proportion of oxygen than it did originally; this excess sometimes amounted to one and a half, two and a half, and even four per cent., and its presence apparently depended upon the vital functions of the included plants being

excited to decompose the carbonic acid exhaled from the soil.

When air is either partially or wholly confined, or rendered stagnant, it is not susceptible of sudden alterations in the elevation or depression of temperature, and therefore plants growing therein can be taken into warm or cold climates that would otherwise prove fatal to their existence; the following is a good illustration of this fact:—

In New Holland, during the month of February, when the temperature was 94° in the shade, a case of plants was prepared for a voyage to this country; in rounding Cape Horn two months subsequently, the temperature fell to 20° ; a month later in the harbour of Rio, it rose to 100° ; and upon crossing the line, it even rose to 120° , and upon arrival in the British Channel, it fell to 40° ; this was during November, and therefore eight months after the plants were enclosed, but they were all in most healthy condition, on account of the insusceptibility of the confined volume of air having protected them from experiencing these extreme changes of temperature with abruptness or irregularity.

Apparatus upon the foregoing principle may be constructed of any size, and if very large, glazed frames are best adapted for the covering; costly and rare plants need not be enclosed, for common ivy, honey-suckle, primroses, anemones, ferns, and mosses, by the luxuriance and beauty of their growth, will amply reward the little trouble thus required for their protection from a vitiated atmosphere, and from the extremes of its temperature.

During a hot and brilliant day, if we look across a tract of dark coloured soil, we may frequently observe that all objects upon it or surrounding it, appear to have a dancing or tremulous motion; this singular phenomenon admits of satisfactory explanation.

The surface of the land becomes exceedingly hot by absorbing heat from the sun, and imparts heat to the

stratum of air immediately incumbent upon its surface, the air so heated becomes lighter, and ascends, whilst a colder and heavier portion descends, and so on, constituting a transparent medium of unequal density, through which the rays of light from surrounding objects do not pass in direct and steady lines,—as they do through a volume of air having an uniform density—but are distorted or refracted with ceaseless rapidity, so that they impinge upon the eye of the observer with wavering irregularity, and convey to the sense an impression that the objects themselves are actually in motion.

The same phenomenon is observed if we look at objects beyond the top of a chimney, from which the heated products of a clear burning fuel are arising without dense smoke; and if the chimney belong to a cottage built in a small hollow, with rocks and trees immediately surrounding it, the distortion of their positions is often very remarkable.

But the examination of this refraction of light appertains to the science of Optics, and not to that of Chemistry; the reception of heat by the land, which is the cause of the phenomenon, is, however, a legitimate branch of the latter science, and therefore it will claim our attention. It has been discovered by the aid of the thermometer, that some soils are more readily heated than others, when equally exposed to the action of the sun; and when they all ultimately acquire an equal elevation of temperature, that some become more readily cooled than others.

Soils principally consisting of white and strongly adhesive clay, are not, generally speaking, readily heated; and containing a very considerable amount of water, the heat soon escapes, because it is immediately concerned in changing part of such water into vapour, which, as will be proved hereafter, contains an enormous store of latent heat.

Soils chiefly consisting of chalk, agree with the foregoing in respect to their heating with difficulty, but as they do not

contain a large amount of water, they do not lose much heat by its evaporation.

Soils exceedingly dark in colour from containing a great proportion of organic, ferruginous, or carbonaceous matters, become more heated than pale coloured soils, when exposed under equal circumstances to the action of solar heat.

"When soils are perfectly dry, those that most readily become heated by the solar rays, likewise cool most rapidly," at the same time it is a remarkable fact that "the darkest coloured dry soil, that which contains abundance of animal and vegetable matter, substances which most facilitate the diminution of temperature, when heated to the same degree, provided it be within the common limits of the effects of solar heat, will cool more slowly than a wet pale soil composed entirely of earthy matter."

A specimen of rich black mould, which presented upon analysis nearly one fourth its weight of vegetable matter, was exposed for an hour to sunshine, during which time its temperature increased from 65° to 88°, whilst a chalk soil, under the same circumstances, had its temperature increased only to 69°; however, upon removing the mould into the shade, where the temperature was 62°, in half an hour it lost 15°, whereas the chalk similarly situated lost only 4°. Portions of brown fertile soil, and barren clay, were accurately dried and then artificially heated to 88°; they were afterwards placed in a room at 57°; in the course of half an hour the brown soil lost 9°, but the clay lost only 6°.

An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a quarter of an hour it was found to have gained the temperature of the room.

The thermometer is an instrument frequently employed throughout the four seasons, but it merely denotes the degrees of heat that air, water, and earth, and other media are capable of imparting, and not the actual quantity of

heat therein contained; several experiments can be performed in illustration of this fact, and their results will lead to the elucidation of important natural phenomena. Introduce the bulb of a thermometer into one pint of water, and then into four pints of water, drawn at the same time from the same spring, the instrument will indicate both portions to be of the same temperature, although it is obvious upon the slightest reflection, that four times as much heat must be present in the one case than in the other, but this heat the thermometer cannot indicate.

To proceed farther in this inquiry, provide two half-pint wide-mouthed glass bottles of similar form and thickness; suspend a pair of common scales from any convenient and steady support, and in each of its pans place one of these bottles, probably they will not balance each other, therefore add small shot and sand to the pan containing the lightest of the two until an equilibrium be effected.

Pour olive oil into one bottle until it be nearly filled, then pour water gradually into the other until it exactly balance the first and its contents, remove both bottles carefully to stand upon a table.

Provide two mercurial thermometers alike in size and graduation, place the bulb of one of these in the olive oil, and that of the other in the water; then carry the bottles thus prepared into a hot room at 70° ; for example, place them side by side upon a table, and let the air of the room be undisturbed by draughts; inspect the thermometers from time to time, and it will be found that the oil becomes warm more quickly than the water, and ultimately that it will attain the temperature of the room in precisely half the time that the water will require to attain the same degree. When the contents of

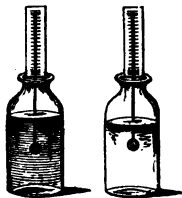


Fig. 28.

the bottles have acquired the temperature of 70° , reverse the conditions of the experiment by carrying them into a cool room or cellar at 40° , for example, and then it will be found upon inspecting the thermometers, that the oil will descend to such temperature—or cool—in precisely half the time that the water will require to descend to the same degree.

The inferences to be drawn from these experiments are, in the first place, that the oil required less heat than the water to elevate its temperature to the thermometric indication of 70° ; and, in the second place, having gained such heat, it parted with it more readily than the water, similarly circumstanced. In chemical nomenclature, these results are denoted by a technical term that conveys a direct and concise meaning; and all technical terms facilitate inquiry when they are perfectly understood, but impede it if employed without proper explanation.

The oil required less heat, and parted with it more readily than the water; or, technically expressed, the capacity of oil for heat is less than that of water; in fact, the oil gained and lost heat with twice the rapidity that the water did; and if, for the sake of a definite mark of comparison, the capacity of the oil for heat be taken as 50, that of the water will be 100; or the fact may be yet more simply expressed, by saying the capacity of oil for heat is half that of water.

Another simple and decisive experiment will prove that equal weights of oil and water, although at the same thermometric temperature, do not contain the same amount of heat; and for the performance of this, the following preparations are required.

Two cylindrical canisters of tin-plate, each being six inches in height, two inches and a half in diameter, and having a cover with a knob in its centre, and a perforation near that about three quarters of an inch in diameter; these covers must fit very tightly, or have small "bayonet

catches," so that upon holding them by their knobs, when fitted on the canisters, these will not fall away, but will require force for their separation.

Two cylinders of tin-plate, in height equal to that of the canisters, but in diameter about an eighth of an inch greater, and open at each of their ends, that the canisters may easily slide through them.

Two earthenware flower-pots, alike in shape and size, in depth equal to the height of the cylinders, but in diameter at bottom about three-quarters of an inch greater than them; two large hyacinth-glasses equal in size and shape; and, lastly, two small mercurial thermometers similarly graduated, and with bulbs small enough to enter the apertures in the covers of the canisters.

Suspend a pair of common scales from any convenient and steady support, and in each of its scales place a canister without its cover, they will probably not balance each other, therefore small shot and sand must be added to the scale containing the lightest of the two until an equilibrium is effected.

Pour olive oil into one canister until within half an inch of its brim, then pour water into the other, until it be sufficient to balance the oil; thus equal weights of the two liquids are obtained; the canisters are then to be removed from the scales, firmly closed with their covers, and the thermometers introduced through their apertures.

Place the canisters to stand upright in a saucepan sufficiently deep and narrow to prevent them from falling upon one side or the other; then pour water into this until the canisters are rather more than half immersed; lastly, place the saucepan over a clear glowing fire that the water may boil.

This it will probably do at, or near, 212° , but whatever degree the thermometer may indicate as the boiling point, of course the same will be imparted to the canisters, their contents will be equally heated, and the thermometers will be equally affected: this is the condition to be fulfilled.

•

Whilst it is in progress, a few more arrangements can be made; select two pieces of wood, each of these being two inches long and sufficiently square to remain firm when thrust half way into each of the small circular apertures of the flower-pots; then place each of these to stand upon the rims of two cups or jars.

Fold about two pounds of clean ice in a flannel, and beat it with a mallet until the ice is broken into pieces about the size of ordinary hail-stones, and if necessary, let it drain upon a sieve.

Thrust a crumpled sheet of thin paper into one end of each cylinder to form a temporary stopper, then place each with this end uppermost to stand in the centre of each flower-pot, and carefully fill the space between the exterior of each cylinder and the interior of each flower-pot with the crushed ice; this is most readily done by dropping in, a small portion at a time, from a wooden spoon; the ice is prevented from entering the cylinders by the paper stoppers, these are next to be removed, and each flower-pot lifted to stand firmly upon the rim of each hyacinth-glass.

If the water boil in the saucepan, remove it from the fire, protect the hands with thick woollen gloves, and lift out each heated canister by the knob of its cover, at the same time, one in the right hand, the other in the left, then drop each at the same moment into each cylinder, and immediately lift up each cylinder completely away that the ice may simultaneously come in contact with each canister.

In this arrangement the canisters are supported one inch above the apertures in the flower-pots by the plugs of wood, these, being square, prevent the ice from falling through, whilst they readily allow the water resulting from its thaw to pass, and by capillary attraction direct it into the respective hyacinth-glasses.

When removed from the boiling water, the water and the oil were of the same thermometric temperature; and if they contained the same amount of heat, or if they had the same

capacity for heat, then in cooling down to the same thermometric degree they should assuredly thaw equal quantities of ice, and equal quantities of water should flow into the glasses.

But the capacity of water for heat is double that of the oil as already stated, and proved, and now additionally confirmed, for when the thermometers indicate that the two liquids have lowered to an equal temperature, it will be found that the water has thawed twice as much ice as the oil; and accordingly there is twice as much water in the hyacinth-glass that supports the flower-pot holding the water canister, than there is in the other that supports the flower-pot holding the oil canister.

The annexed engraving shows this striking result, and may aid the whole description that has been given concerning the performance of the experiment.

By experiments conducted with extreme precision, the fact is established that different substances under similar conditions, may impart the same temperature to the thermometer, although they inherently

contain very different quantities of heat; and it is proved that water possesses the greatest capacity for heat, and the least sensibility to heat, of any known substance; the important consequences of this extraordinary property of water throughout the Creation will become fully apparent at a future season.

Solids, liquids, gases, and vapours, although of the same temperature, have different capacities for heat, and these are



Fig. 29.

most singularly affected by changes in their physical states of density.

Thus, at common temperatures, if a given bulk of water weigh 1000, a similar bulk of lead will weigh 11350; if this be suddenly and powerfully compressed by machinery, its integral particles will be thrust or packed into less bulk than they originally occupied, the metal becomes more compact, and specifically dense, and if its weight be now compared with that of an equal bulk of water it may be found increased to 11360.

Lead, in common with other substances, contains a certain amount of heat, or has a certain capacity for heat; and if a strip of the metal be placed on an anvil, then suddenly and forcibly beaten with a hammer, its density will be increased, but its capacity for heat will be diminished; the integral particles of the metal, being compacted into a smaller than their original bulk, have no room for all the original heat, some therefore must escape, it does so, and warms the lead to a degree that is painful to the hand, and it will immediately kindle a piece of phosphorus, or the phosphoric tip of a match.

A dextrous blacksmith will place the point of a soft iron horse-shoe nail upon the anvil, then strike it only two violent blows with a hammer, and the point will instantly become red-hot, on account of the density of the metal being so suddenly increased, and its capacity for heat so excessively diminished.

In further elucidation of these curious matters — which may at present appear to have no connexion with the Chemistry of the Four Seasons—a piece of sponge may represent the metal, lead, or iron, it has in its ordinary state a certain capacity for holding water; so has the metal a certain capacity for holding heat; when the sponge is squeezed its particles are brought closer together, it has less capacity for water, and accordingly some will run out; so the metal when struck, has its particles brought closer together, and it has less capacity for heat, and some will escape.

Change of density in liquids is also attended by change of their capacity for heat, and Chemistry can furnish many striking experiments in illustration of this fact, one of these however will be sufficient for our present purpose.

Provide an apparatus, consisting of a glass tube, twelve or fourteen inches long, half an inch in diameter, closed at one end, and enlarged at the other into two bulbs about three inches in diameter, connected by a short neck of the same size as the tube; the bulb farthest from it has a mouth provided with an accurately fitted stopper, slightly touched on its ground part with pomatum for a reason already described.

Remove the stopper, and holding the apparatus upright by the bulb to which the stopper belongs, pour water into it, until the tube and lower bulb be filled; then pour in alcohol, until the upper bulb and its mouth be filled; carefully insert the stopper, and lastly wipe away the little quantity of alcohol that will overflow.

In this arrangement, the water, being the heaviest liquid, will remain below, and distinct from the lighter alcohol, the two liquids are prevented from mixing immediately by the narrowness of the neck connecting the bulbs, and they are both of the same thermometric temperature.

Place the palm of the hand over the stopper, grasp it and the bulb, and invert the apparatus that the tube may now stand perpendicularly; thus placed, the heavy water will fall into the light spirit, and the light spirit will run into the heavy water, or in other words, the two will mingle, and the bulbs will become sensibly warm: the tube will not appear full as it was originally: the ground stopper being held firmly during this proceeding has prevented any portion of the mixed liquids from escaping, and yet the tube is remarkably deficient in its contents, and the bulbs are warm; these phenomena admit of explanation; the light alcohol



Fig. 30.

chemically combines with the water, and has its density increased, it therefore occupies a smaller bulk than at first, or shrinks; it has its capacity for heat diminished, a portion is consequently expelled, and becomes sensible to the hand.

These experiments with solids and liquids are preliminary to others upon the atmosphere, which will most concern our present inquiry concerning the phenomena of summer admitting of chemical interpretation, and we shall soon discover that changes in the density of the atmosphere by condensation and rarefaction, produce alterations in its temperature, elevating it in the one case, and depressing it in the other.

All æriform substances, on account of their wonderful elasticity, admit of more sudden condensation and rarefaction than either solids or liquids, and therefore experiments upon such highly attenuated, mobile, and generally invisible matters, are not only curious but instructive.

A simple apparatus is constructed for the performance of an experiment in proof of the fact that the condensation of air diminishes its capacity for heat; this apparatus consists of a well annealed and perfectly cylindrical tube of



Fig. 31.

glass, fourteen inches long, a quarter of an inch thick, and rather more than a quarter of an inch internal diameter or bore; one end of this tube is closed with hard, resinous cement, which likewise secures around its exterior a brass cap terminating in a ball about an inch and a half in diameter, whilst the other end of the tube is open, but its circumference bound with a brass band about two inches broad, cemented on to prevent the glass from being chipped.

The second part of the apparatus consists of a rod of well tempered steel, about one inch longer than the glass tube,

but rather smaller than its bore, for about twelve inches; one end of this rod is firmly screwed into a flat brass knob about one inch in diameter, whilst the other end is enlarged and closely packed with oiled leather to form a piston which accurately fits the tube, the extremity of the piston has either a small hook, or a small concavity to hold a fragment of perfectly dry amadou tinder, about half the size of a pea. The bore of the glass tube contains a certain volume of air; insert the piston, place its brass knob upon a solid table, that the brass ball may be uppermost; grasp this with the right hand, steady the tube with the left, then with one sudden powerful jerk, thrust the tube down as far as possible; a vivid flash of light will instantaneously appear; then quickly withdraw the piston, and the tinder will be found burning as perfectly as though it had been kindled at an ordinary flame. The remarkable phenomenon can be thus explained: by the sudden powerful compression, condensation or increase of the density of the volume of air in the tube, its capacity for heat is diminished, or, in other words, the sudden thrust of the piston forced heat from the air, as the sudden blow of the hammer beat heat from the lead in the first experiment, this aerial heat is sufficiently intense to cause the tinder to kindle.

Then, if so much intense heat be elicited from so small a volume of air as that contained in the glass tube, an inconceivably enormous amount must be latent in the vast atmosphere, in readiness for emission should its density be increased during the changes of the four seasons.

Diminution of the density of the air, or in other words its rarefaction or expansion, increases its capacity for heat, and produces diminution of temperature, or popularly an effect of cold; an experiment in proof of this curious fact may be performed by the aid of an air-pump, and most persons are now familiar with the construction of this important apparatus.

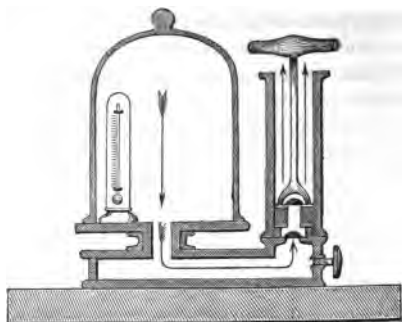


Fig. 32.

For simplicity of description, the accompanying engraving represents the section of an air-pump, with merely a single barrel or cylinder; at the bottom of this is a small chamber containing a hemispherical valve, and upon the top of the piston is a similar valve; these are both arranged to open upwards; the barrel is unclosed at its top or mouth, and the two featherless darts indicate the air that it of course includes, as far as the valve upon the piston.

The horizontal tube is connected on the one hand with the valve chamber, and on the other with the central aperture of a flat, smooth, and circular plate of brass, technically called the pump-plate, upon which, and near its edge is placed an extremely delicate mercurial thermometer, attached to a standard having a firm base; then the smooth ground rim of a large bell-glass, technically called a receiver, is slightly touched around with pomatum, and placed over this arrangement, with a slight pressure to rest evenly on the pump-plate.

The air contained in the horizontal tube, and that contained in the receiver thus coalesce, and form one volume

of equal density and temperature, the degree of which must be noted. Grasp the cross-handle of the piston-rod, and by it suddenly raise the piston to the mouth of the barrel; this simple act will instantly affect both the density and the



Fig. 33.

temperature of the air as follows:—The air contained in the barrel of the pump, as indicated by the featherless darts, is mechanically lifted up, and expelled from its mouth, as the piston is raised; the space in the barrel, between the bottom of the piston and the valve of the chamber, would therefore be void of air; but this valve being arranged to open upwards only, the volume of air in the receiver, on account of its extraordinary inherent property of elasticity, or property of self-adjustment to the conditions under which it is placed, expands immediately, passes in the direction of the perpendicular and horizontal feathered darts, lifts the valve, and fills the barrel, as indicated by the two double-barbed darts in the annexed figure.

The heat that was concentrated within the limit of the original volume of air, in its ordinary state of density, is now diffused throughout the expanded or rarefied volume; or, if the expression be permitted, the individual particles of heat are more remoted from each other than they were, and do not affect the bulb of the thermometer with their former intensity; it therefore will indicate a depression of temperature.

By thrusting the piston downwards, the power of the air below, indicated by the two double-barbed darts, will lift the valve, pass through the aperture that it incloses, and fill the barrel, as formerly indicated by the two featherless darts, whilst its pressure will cause the valve of the chamber to close its aperture firmly, and so prevent the return or retrogression of any portion of the air to the receiver. By raising the piston a second time, another

demand is made upon the air in the receiver ; it again expands, lifts the valve of the chamber, and fills the barrel ; its density is now less, its rarefaction is now greater, its heat is now more diffused, and the thermometer will again denote a depression of temperature ; by thus proceeding to work the piston downwards and upwards, repeated demands will be made upon the air in the receiver to supply the repeated losses of that from the barrel, until its elasticity is so attenuated as to have no power to lift the valve of the chamber, or technically speaking until it be exhausted, and the thermometer will indicate a depression of several degrees of temperature.

In this state of things it will be found impossible to lift the receiver from the pump-plate, because it is firmly thrust thereon by the pressure of the external atmosphere, which amounts to about fifteen pounds upon each square inch of surface opposed to its action ; this pressure manifests the endeavour of the external atmosphere to enter, and to restore, the equilibrium of density, disturbed by the action of the pump. By removing the small screw that is placed under the valve chamber, the external atmosphere will immediately enter through the aperture so disclosed, into the horizontal tube and the glass receiver, the equilibrium will be restored, the density of the whole volume of the included air will be the same as it was originally, the thermometer will indicate the original temperature, the receiver will become loose, and may be lifted from the plate.

In the foregoing experiment, at each rapid ascent of the piston, the interior of the receiver will appear as though it were filled with mist ; it is really so filled, and for the following reason :—the atmosphere invariably contains the vapour of water ; a certain amount of heat is requisite to produce and to maintain such vapour invisibly diffused throughout its volume ; the portion of air included by the receiver was under these conditions, but suddenly compelled to expand, the heat was as suddenly diffused throughout

the expanded volume, the aqueous vapour was chilled by this remotion of heat, and condensed into minute vesicles of water to form an artificial mist.

This beautiful phenomenon may be more perfectly observed if a wet sponge be placed upon the pump-plate, and covered with the receiver for about a quarter of an hour, the included air will thus become saturated with aqueous vapour, and then, upon proceeding to exhaustion, it will condense as mist in abundance.

Chemistry adduces this experiment in explanation of the formation of a natural mist: the invisible heated watery vapour present in the atmosphere becoming visible minute vesicles of water as its temperature falls, either by sudden local rarefaction or by coming into contact with cold surfaces of the earth and waters.

To impress these curious and important facts upon the mind, take the following example:—suppose a cubic foot of atmospheric air to contain a certain number of particles of heat, equally diffused throughout such volume of its elementary and compound constituents, and capable of affecting the thermometer to a given degree; if this volume be mechanically compressed to one-tenth of a cubic foot, of course there will be ten times as many particles of heat concentrated into that tenth as there were, and the thermometer would indicate a rise of temperature; this was illustrated to an extreme degree by the experiment of kindling tinder by the compression of air. On the other hand, suppose the cubic foot of atmospheric air to be expanded to ten cubic feet, the particles of heat would be so extensively diffused, so extremely remoted, that the thermometer would indicate depression of temperature; this was illustrated by the experiment with the air-pump.

These experiments of the chemical laboratory furnish explanations of several natural phenomena that may be now examined.

An enormous store of heat is contained in the atmosphere, but this medium is not of uniform density throughout from the earth to its own confines; the portions directly incumbent upon the earth are most dense, because they



Fig. 34.

sustain the weight of superincumbent portions; as, to use a very humble simile, the hay at the bottom of a rick is most compact, because it bears the weight of that above; or an idea of the fact may be gained from the annexed engraving, the gradual shading denoting the gradual diminution in the density of the atmosphere in proportion to its altitude.

The compression of the lower by the upper portion of the atmosphere alters its capacity for heat, as it was altered by the compression of the piston in the experiment with the tinder, and accordingly heat escapes from it in quantity suited to the time and season for the welfare of the animated creation.

If we ascend a lofty mountain, and thus approach many hundred feet nearer to the sun than we were in the valley at its base, we might expect to find the air considerably warmer, but we experience the contrary, the air is intensely cold. Chemistry can explain the cause of this phenomenon: it has been stated that the sun does not heat the transparent atmosphere, and on the mountain-summit it is extremely rarefied, attenuated, and free from pressure; accordingly the heat that it derived from contact with the warm earth is most extensively diffused, and in a given volume of the air on the mountain summit there is not the same amount of heat that there is in an equal volume of the denser air in the valley. Again, warm air in ascending from the valley, expands, and remotion of heat, or popularly cold, ensues, and very frequently to such an extent that the aqueous vapour of the air condenses in vesicles, forming

clouds; these vesicles, as they coalesce, are presumed to form rain drops, or they are congealed into snow which then clothes the mountain summit.

Chemistry has determined the fact that air, in rising from the level of the sea, becomes nearly one degree colder for the first two hundred feet of ascent, and altogether about fifty degrees colder in rising fifteen thousand feet; thus water would freeze at this elevation even near the equator, where the temperature of the low plains is at least 80° ; for this reason the summits of lofty mountains are covered with perpetual snow, and the altitude at which it occurs is called the snow-line, or the line of perpetual congelation.

The Andes present a magnificent illustration of these phenomena consequent upon the varying capacity of air for heat; placed nearly under the equator, they tower from parching sands; about their middle height the climate is temperate; their summits are crowned with eternal snow, and these ranges of temperature are always distinct; the hot winds from below, if they ascend, become gradually cooled by expansion, and if by any cause the cold air be driven downwards, it is condensed, and rendered warmer in its fall.

How grand, how harmonious are these adjustments of the powers and properties of matter, by the hand of their Creator, who "made the weight for the winds, and weighed out the waters by measure;" how eminently calculated are they to inspire us with emotions of admiration and gratitude towards the Author of our being!

The Creator has ordained the level surface of the earth to be the chief dwelling place of mankind, and has commanded the atmosphere, directly incumbent upon it, to be of the just weight or density, and to contain the due amount of heat which vitality requires for the proper maintenance of its manifold recondite functions, whilst, on greater elevations which are but thinly peopled, or on mountain summits which are but rarely visited, these wondrous agents, air

and heat, are attenuated and weak, because they are not required in plenitude and power for the support of life.

Exploring and investigating throughout the treasures of the Creation, we become more and more impressed with the truth that is founded upon the most miraculous scale of wisdom and beneficence, and that bounteous gifts are not indiscriminately scattered where they would be useless to organic beings, but are lavishly presented where required for their manifold wants. Great, inexpressibly great, is the delight in thus being permitted to follow the marvellous works of the Creator, to trace the unbounded power and transcendant goodness which are displayed alike in the mightiest and the lowliest parts of the universe.

"In the heavens hath He set a tabernacle for the sun, which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race; his going forth is from the end of heaven, and his circuit unto the ends of it, and there is nothing hid from the heat thereof."

In the poetical imagery of the foregoing passage, are set forth the powerful and genial effects of solar light and heat; let us trace the unerring laws by which they are controlled to work together for our good.

During the brilliant zenith of summer—even in torrid climes—although the heat of the sun impinge upon the earth with vast and continued power, its degree is so miraculously adjusted and restrained by Providence, that it never attains sufficient intensity to cause the destruction of organic bodies by combustion; nay more, the chemist, after all his extensive researches throughout the varied objects which come within his cognizance, cannot discover a single element or a single compound in a native state which is capable of inflaming by solar heat.

If the heat of the sun were not thus miraculously adjusted to the nature of the earth and its productions, if the earth were capable of receiving and retaining the whole amount of heat that is constantly thrown upon it by the

sun, if the atmosphere were capable of being heated by direct conduction of such heat, the temperature of the globe would increase probably 800° in a single year; and, above all, if the whole atmosphere were to sustain sudden condensation of its volume, the temperature would instantly exceed that of red hot iron.

Thus, all living things would perish, the waters would be dried up, and the earth, by the accumulated heat, would ultimately "pass away."

Considering the elements and constituent parts of which this terraqueous globe is composed, a slight disturbance in the present harmony and order of their adjustments would cause its instantaneous destruction.

These are facts which become apparent during the pursuit of science, and like all others so discovered by man, they emanate from "The Fountain of all truth;" pure science corroborates the testimony of Scripture, which recounts the first revolutions of the Creation, and which equally foretells the last. Scripture recounts,—“That by the word of God the heavens were of old, and the earth, standing out of the water, and in the water.” “Whereby the world that then was, being overflowed with water, perished.”

Scripture foretells,—“But the heavens and the earth, which are now, by the same word are kept in store, reserved unto fire against the day of judgment and perdition of ungodly men.”

“In the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also, and the works that are therein shall be burned up.”

The Hand of Providence is beneficially extended for the protection and relief of the animated creation when languishing and drooping beneath the parching heat of summer, for Chemistry discovers that even during its most intense degree, the atmosphere is never absolutely devoid of aqueous vapour—or anhydrous—and that by a recondite

power it is commanded from its invisible aërial expanse, and gathered into opaque clouds, which hover between the sun and the earth, and act as veils in preventing the direct transmission of heat; or they complete their wondrous work of relief by relinquishing part of their water in refreshing showers, and gaining sufficient heat for converting the remainder into invisible vapour, they disappear with it, to perform the same genial office upon other suffering districts of the earth.

The water of the summer shower is eagerly imbibed by the arid earth, and its vegetable clothing, whose leaves and flowers immediately send forth delicious fragrance in grateful return for such miraculous and salutary aid.

This fragrance emitted by vegetable productions appears to depend upon their functions being suddenly excited by the contact of water to elaborate aromatic principles, having an excess of the element hydrogen, its exact cause however is unknown; but the peculiar odour which is emitted by barren earth after a shower, is proved to depend upon the combination of water with the aluminous and ferruginous matters of the soil.

The water of the shower, having yielded refreshment to the earth and its productions, is again destined to ascend as vapour into the atmosphere under the influence of heat derived from the earth: the delightful coolness soon after a shower depends upon the evaporation which carries away the superfluous heat; it is very much facilitated if the air be in motion at the same time, and a considerable reduction of temperature is thus effected. It has been stated that evaporation is dependent upon the temperature of the air, the velocity of its movement, and the extent of the watery surface exposed to its action; the rate at which it ensues may be judged by reference to the annexed table, showing the number of grains of water that evaporate per minute from a circular surface six inches in diameter during different temperatures and movements of the atmosphere.

<i>Temperature.</i>	<i>Calm.</i>	<i>Breeze.</i>	<i>High wind.</i>
Fahrenheit.	Grains.	Grains.	Grains.
35° . .	0·95 . .	1·22 . .	1·49
45 . .	1·36 . .	1·75 . .	2·13
55 . .	1·90 . .	2·43 . .	2·98
65 . .	2·62 . .	3·37 . .	4·12
75 . .	3·65 . .	4·68 . .	5·72
85 . .	4·92 . .	6·49 . .	8·04

The amounts of the evaporation of water in the above table are rather greater than those of the natural phenomenon, because they refer to air artificially dried, and, as already stated, the atmosphere is never anhydrous during any one of the four seasons.

As evaporation proceeds from any natural bulk of water that is confined within its banks, and has no visible outlet therefrom, in proportion as the pure water rises in vapour, the fixed matters that it held in solution become more and more concentrated in the bulk that remains, and of course it increases in saline taste, thus producing what are known as salt lakes, or inland seas, the most remarkable of which are the lake Asphaltites, or Dead Sea, the brook Cedron, and the Caspian Sea.

For the conversion of water into vapour, heat is in all cases required, and the surfaces which impart it, of course become diminished in temperature or become cold; advantage is taken of this fact for obtaining artificial reduction of temperature, even during the summer of tropical climates; thus in India, apartments of houses are often separated from the courts by curtains instead of walls, and these being continually sprinkled with water, its rapid evaporation occasions a reduction of temperature from 10° to 15° below that of the atmosphere; this is also done in Sicily and Malta, and many other countries during the prevalence of hot winds, and is facilitated by putting the air into motion by fans.

The door-ways of apartments or tents in India are often fitted with light frames of bamboo, enclosing the dried roots of a fragrant grass sparingly distributed in vertical lines all over them; on these water is occasionally thrown, which, gently trickling down and evaporating, reduces the temperature of the air that passes through the frame-work from the external atmosphere to the interior of the apartments or tents.

Even in England, during the height of summer heat, we very frequently sprinkle water upon the ground or pavement in front of our houses, and experience relief from the reduction of temperature that takes place.

The Egyptians availed themselves of this production of cold by evaporation for the purpose of cooling water; pitchers were filled with the coldest water that could be obtained, and servants were employed throughout the night to keep the outsides of these constantly wetted with water; as it evaporated, it abstracted heat from the pitchers and their contents, and when the utmost depression of temperature was gained, the pitchers were bound round with bands of straw, which being a very imperfect conductor, prevented the water from immediately gaining the heat of the surrounding atmosphere.

The porous vessels of earthenware which are used as wine-coolers act upon the same principle; being dipped in water, they imbibe a large portion by capillary attraction; this gradually evaporates upon their removal into the air, and as part of the heat requisite for the production of vapour will be taken from a bottle of wine placed in the vessel, a considerable diminution of temperature is obtained.

It is proverbially dangerous to remain in wet clothes, especially when exposed to a draught of air, for evaporation is then excited to proceed with such rapidity that the animal heat of the body is lowered much below its natural

standard, and produces the injurious effects of chill; if exercise be taken, there is less danger, because the muscular action incites the evolution of animal heat in proportion as it is removed by evaporation. The healthy natural temperature of the human body is between 96° and 98° ; when very active exercise is taken, or when exposed to a great degree of heat, there is a rise of bodily temperature which is conducive to health, and the most injurious effects would ensue if it were not for the copious perspiration which withdraws heat from the system, and cools it down to the healthy standard; if this perspiration be checked in its escape by air-tight or water-proof clothing, the consequences will be serious if not fatal. By merely placing the hand on a cold, dry plate of glass, or in a bell-glass, the watery vapour that escapes from the skin or perspiration will condense and become perceptible, as it was found to do from the surfaces of leaves in a former experiment, page 118.

We immediately experience great relief and coolness upon applying a cambric handkerchief to the perspiring brow, because the fine fibres of the cambric have an extremely strong capillary attraction for moisture, and a good conducting power as regards heat; thus, by rapidly abstracting both moisture and heat from the skin, the refreshing sensation of coldness is produced: the case is different with a cotton handkerchief, because its coarse fibres have neither strong capillary attraction, nor good conducting power, and its application to the skin produces a sensation of heat.

The diminution of temperature—cold—produced by evaporation, admits of several experimental illustrations; for example: let the bulb of a thermometer be smoothly covered with fine cambric, then, by keeping this constantly wetted with water, whilst the thermometer is suspended in a strong draught, or blown upon from a pair of bellows, the thermometric liquid, be it either mercury or alcohol, will quickly



Fig. 35.

descend to a lower degree of the graduated scale.

The accompanying figure represents a glass tube, about a quarter of an inch

internal diameter, and ten inches long, having at one extremity a bulb an inch and a half in diameter, and at the other, which is bent like a shepherd's crook, a second bulb, of similar dimensions to the first, but having a short and fine neck; through this pure water is introduced, until the first or plain bulb is about half filled: then, by cautiously holding it over the flame of a spirit-lamp, the water will soon boil, its steam will expel all the air originally contained in the instrument, and issue freely from the small orifice of the neck, to which the flame of the lamp is then suddenly applied, that it may fairly melt the glass together, and thus effectually close the orifice, or technically speaking—seal it hermetically.

The apparatus is thus finished, and when cold, if it be shaken, the water will fall through the tube from the one bulb to the other, not with its ordinary gurgling sound, but with a sharp clicking noise, because there is no air within to resist its rapid fall, or to act as an elastic spring against its direct contact with the glass, or technically speaking, the water is in *vacuo*, as regards the absence of air, and only subject to the pressure of its own vapour.

If the apparatus be now held slightly inclined—as shown in the figure—with the hand grasping the plain bulb, the expansion of the vapour will force the greater portion of the water into the other, the moment after it has done so will be succeeded by a rapid bubbling, and the hand will experience a sensation of cold, because heat is suddenly abstracted from it to enable the small portion of water adherent within the bulb to assume the state of vapour.

The empty bulb may now be placed in a mixture of equal

parts of finely powdered ice and salt, well rubbed together, contained in a large finger-glass, and then all covered with a glass shade in order that another phenomenon may take place.

The mixture of ice and salt produces a very low temperature—for a reason to be given hereafter—it immediately condenses the vapour in the bulb into water, and then solidifies this into ice; but the water contained in the upper bulb immediately emits a portion of vapour to supply the loss of that below; this in turn is condensed and solidified, fresh vapour is again emitted from above, and again condensed and solidified, and so on, until the water in the upper bulb, by these successive demands for its vapour, has parted with so much heat that it can no longer remain liquid, but is forced to become solid, or to freeze, although so far removed from the source of the diminution of temperature in the finger-glass. The instrument is accordingly known in the science of Chemistry as the cryophorus, or ice-bearer, and when it has borne the ice, the bell-glass should be lifted away, and the instrument removed: when the ice has thawed, it may be used repeatedly, even at the height of summer, plunged as directed into the freezing mixture, and covered with the glass shade to prevent the direct access of the warm atmosphere to the upper bulb.

The cryophorus illustrates the remarkable fact, that water may be frozen by the depression of temperature produced during its own evaporation, but the more particular consideration of the immutable law that directs the transition of liquid water into solid ice, will demand a large share of our attention when we enter upon the chemical phenomena of winter.



Fig. 36.

From the experiment so recently performed, and the tabular statement already presented it must be obvious that water is capable of evaporating at a very low temperature, and in consequence of the lavish profusion in which it is poured around the globe, the cause of many extraordinary and important phenomena may be safely referred to its own phenomenon of evaporation. Accurate experiments appear to warrant a conclusion that the annual evaporation of water averages thirty inches, meaning, that the vapour if reconverted into water would cover the surface from whence it ascended to a depth of thirty inches; then, the surface of all the waters of the globe being assumed at one hundred and twenty-eight million of geographical miles, nearly sixty thousand cubic miles of water would be annually changed into vapour. The presence of aqueous vapour in the atmosphere is indicated by its condensation upon a cold surface, as for example, upon that of a decanter containing water drawn from a deep and cold spring; and yet more satisfactorily by the employment of substances which have a strong chemical attraction for watery vapour, from these, pearlash—carbonate of potassa—may be selected to illustrate the fact.

Take the tare of a small earthenware saucer, then carefully weigh into it an ounce of pearlash, and leave it exposed in the scale pan for a few hours, even in the driest weather, and it will be observed to preponderate, this is on account of its attraction or affinity for water, and if it be left for some days, although thoroughly protected from rain, the solid pearlash will change into a thick oily liquid, which is a strong solution of the compound in water attracted from the atmosphere; pearlash is accordingly denoted as a hygroscopic and deliquescent substance.

It is popularly known that clothes wetted with sea water will seldom become perfectly dry; this is because it contains chloride of sodium, chloride of magnesium, and chloride of calcium, the first being hygroscopic, and the two latter deliquescent, so that in place of the clothes drying perfectly

they absorb moisture from the air, with more or less avidity according to the temperature: thus in very hot and dry weather, the clothes that have been wetted with sea water will be covered with a white incrustation consisting of the saline matters deposited by the evaporation of the water that held them in solution: but these will soon disappear upon the approach of damp weather, as they deliquesce and dissolve in the moisture of the atmosphere.

Hence a sea-weed, being thoroughly imbued with the above saline matters, forms a good natural hygroscope, their alternate appearance and disappearance, its crispness at one time and its softness at another, indicating changes in the dryness and dampness of the weather.

If a large sponge be dipped in sea water, and then squeezed almost dry, upon being accurately balanced in a pair of scales suspended from a steady support, it will be found to preponderate, or to ascend according to the relative dampness or dryness of the weather.

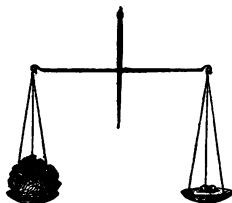


Fig. 37.

It by no means follows that hygroscopic substances should contain deliquescent salts, for many do not, yet their physical, fibrous, or capillary structure is such as to enable them to absorb water mechanically, and thus become affected in form. This is the case with the beard of the wild oat; it is very commonly placed in a small circular glazed box at the top of the household barometer or weather-glass, and by twisting or untwisting during atmospherical changes in the local quantity of watery vapour carries round a piece of straw as an index to DRY and MOIST engraved upon the box plate.

The weather-house is a very ingenious and accurate hygroscope, well-known especially to husbandmen; it consists of a small model of a building having two archways separated by an intervening pier or column, one end of a piece of

harp or violin string is secured to the roof, and passed down the back of the pier to carry at the other end a horizontal cross wire, so bent from its centre where the string is attached, that its opposite extremities may proceed into the opposite archways, and support on the one hand a male, and on the other a female figure. The harp or violin string is then gently turned, and so adjusted that the figures may be parallel beneath the archways, and as the string is a hygroscopic substance—like the beard of the wild oat,—it will twist or untwist according to the dryness or dampness of the air, and in the former case cause the cross-wire to turn that the female figure may advance from its arch, whilst in the latter case cause the male figure to advance.

This weather-house, and another contrivance upon the same principle nearly as popularly known called the monk and cowl, to indicate changes in the humidity and dryness of the atmosphere with correctness, should always be placed in a hall or passage, where the natural temperature is unaffected by the artificial heat of a fire; for if either be placed in a warm dry room, or on the mantelshelf—as very commonly but injudiciously done—the female figure will always be beyond its arch, and the cowl always thrown back from the head of the figure of the monk, although the weather out of doors may be extremely damp or rainy.

The atmosphere being continually in motion from the disturbance of its equilibrium by heat, performs a most important part throughout the Creation; the tropical regions are refreshed, and their temperature prevented from attaining a degree insupportable by the human frame, by the cool currents that arrive from the polar regions; and on the other hand these have the severity of their cold modified by the arrival of warmer gales from the tropical regions.

Tropical islands and coasts are subject to the refreshing agency of sea and land breezes, these result from the motion of the atmosphere in seeking to restore the disturbance of equilibrium that it has sustained by heat.

Chemistry presents an explanation of these phenomena in the following terms:—the solar beams are incapable of elevating the temperature of the transparent atmosphere or even of the transparent water of the ocean in any remarkable degree, but the solar beams are capable of heating the opaque surface of the earth very considerably; therefore an island exposed to a tropical sun, has its soil greatly elevated in temperature and communicates heat to the air by which convection is established, a strong ascending current is produced in one portion of air, whilst another portion of air from the cooler surface of the ocean glides inland to restore the equilibrium and this constitutes the sea breeze.

During the night, the surface of the island, no longer subject to the direct influence of the sun, becomes much cooler than the superincumbent air, and causes it to contract in volume, and to become heavier, it therefore sinks and spreads around, producing the land breeze; this is frequently loaded with unhealthy exhalations from decomposing vegetation, whilst the sea-breeze is salubrious and fresh.

Although water is so essential to the growth of vegetables, if it remain in them after they are removed from the soil, or deprived of vitality, it is the most active agent in causing their decay and corruption; and in order to preserve them they must be dried to a very great extent, but always short of the degree of temperature which would cause a new arrangement of their ultimate elements, or cause decomposition.

The atmosphere, on account of its strong chemical affinity for water and its miraculous adjustment of temperature, is a grand natural agent for effecting this desiccation generally, and of the hay and corn harvest particularly. The long green grass, as it falls beneath the scythe of the mower, is extremely succulent or abundant in water, and if collected into heaps it would soon putrify and become worthless; the careful and provident husbandman, knowing

this fact from experience, not only chooses the most settled weather for the commencement of mowing, but engages a troop of active work-people to follow directly in the track of the mowers, to shake and turn the green swathes about, that all may be quickly and effectually dried, by evaporation of the moisture in the warm air; when this is done the hay can be stacked without danger; it is no longer prone to rot, but will remain for months unchanged as a fragrant nutritious store of provender against the time of need.

The very best sun-dried hay generally contains upon the average from fourteen to fifteen per cent. of water; but this quantity does not interfere with its preservation.

The weather is not always propitious during hay harvest; heavy showers are very frequent, these saturate the newly mown grass, and dissolve out a considerable proportion of its nutritious matter, and also load the air with so much vapour that no drying can possibly ensue until fine days arrive.

It is an old saying that "hills draw the wet," or that "hills draw the clouds;" but they have no inherent or specific attraction in this respect; they are only surfaces of the earth, projecting considerably above its ocean level, and thus, being nearest to the clouds, they soonest receive the rain, and often in such abundance that it swells into floods, which, descending impetuously on the recently mown low lands, suddenly inundate them, and carry off the hay.

This disaster is not only confined to the immediate districts in which it originated, but is frequently extended to others, miles remote, as the flood rolls onward to seek its level; every possible means are therefore taken by the husbandman for preventing the total loss of the valued crops upon which his hopes of future prosperity were anxiously founded; and even if the means prove effectual in arresting or collecting a great portion of the hay, it then requires fair weather for drying, and after all it is frequently

found to be greatly damaged, not only by the solvent power of the water upon its nutritious principles, but by sandy and earthy matters deposited upon it by the mud.

During the anxiety and hurry consequent upon unpropitious weather, the husbandman is often compelled to stack the hay whilst it is damp; but he generally takes the precaution of leaving one or more vacant spaces, reaching from the bottom to the top of the stack to admit air, and to allow of moisture evaporating from the hay, and thus the chance of its heating or firing is greatly, if not wholly, diminished.

When a stack consisting of many tons of hay is burned, either from being kindled by natural causes, or by the accidental contact of household fire, or by the wilful application of the match of an incendiary, the only remaining traces of the originally valuable property are a few pounds weight of vitrified ashes.

The chemist, during his manifold experimental researches, examines the elements and compounds which are required for the growth of "the grass of the field," and he discovers, unless the earth silica and the alkali potassa be simultaneously and proportionately present in the soil of the grass-land, that it will not yield a full crop, however propitious may be the seasons for its growth.

He discovers that the minute terminal fibres of every kind of grass, during its vitality, have the extraordinary power of selecting and withdrawing these two inorganic compounds, silica and potassa, from a proper soil, and of elaborating them as glistening clothing for the organic structures of the stems and blades; and when the vitality of the grass is destroyed by the scythe of the mower, the inorganic compound still remain in the dead and withered hay.

The chemist prepares a mixture of silica and potassa, he heats this in a fierce fire, he then finds that the two primary solid compounds combine and produce a secondary liquid



and of oat straw only four pounds; the growth of beans and of beet demands none of the earthy and metallic compounds which are so imperatively requisite for that of wheat or other grain.

The insolubility and permanence of the siliceous clothing of straw, point it out to the husbandman as the best natural material for covering hay-stacks and corn-ricks in the form of thatch; long unbroken straw is selected for this purpose, as it is waterproof, and will allow the rain to trickle freely from its surface; broken straw will not answer, because its siliceous clothing is so fractured by the flail or thrashing machine as to be full of fissures or capillary channels, which would receive and retain a considerable portion of the rains of autumn, or the snow-waters of early spring, and the organic matter would soon become rotten: therefore such covering would be useless as a protection against any future inclemency of weather.

A thick layer of good thatch is a covering not only waterproof, but of exceedingly imperfect conducting power, on account of the silica and lignin or woody fibre of which its straws consist, and the air with which they are filled, equally preventing the sudden penetration of heat or cold; thus in summer, ice may be prevented from thawing by covering it thickly with straw, and in winter, fruits may be preserved from frost by similar means.

The bungalows of India are built with baked or unbaked bricks, and they are generally thickly thatched, to prevent the transmission of heat; so are tents likewise protected from sun and rain by a thick straw thatch laid on frames of bamboo.

Another example of the bad conducting power of the earth, and straw or dried leaves, may be here mentioned, as it is of much practical utility. In Italy snow is collected with as much assiduity as ice in England; the country surrounding the city of Naples is too flat and warm to allow snow to remain on the ground in sufficient quantity to be

collected; but the chain of the Apennines, traversing Italy from the north to south, furnishes an inexhaustible supply.

A few of the loftiest of these mountains have their summits above the line of perpetual congelation, accordingly they are clothed with snow throughout all the changes of the four seasons, but in the greater part of the range below the line of perpetual congelation the snow of winter melts about the month of May.

The Neapolitans excavate deep pits or wells on the sides of the mountains, or select any natural caves which may be found; and into these they throw, during the winter season, thick pure layers of snow, collected from the mountains; each layer is pressed firmly before another is added, and thus the pits, wells, or caves are completely filled.

When this is done, a large quantity of straw, or of dried leaves heaped upon the upper layer of snow, preserves it from the heating influence of the external atmosphere; and as the cavities are either artificially made or selected from such as naturally exist on the northern aspect of the mountains—to avoid as much as possible the direct rays of the sun, and are moreover at a very great elevation—they maintain a very low temperature, even during the intense heat of summer; the snow diggers then proceed to the cavities, extract the snow, and bring it into the city, where it is sold at a regulated price for the purpose of cooling water and other beverages.

During a summer day, an extreme closeness, or oppressive sultriness, an extraordinary transparency of the atmosphere, an unusual tranquillity of the animal and vegetable kingdoms, and a painfully acute sensibility of the human ear to accidental sounds, may—with few exceptions—be regarded as sure forebodings of a thunder-storm.

This awful and astounding phenomenon is still ordained to manifest itself throughout the atmosphere, as it was during remote ages, when the Psalmist, in extolling the power of the Almighty, recorded,—“The voice of thy thun-

der was in the heavens, the lightnings lightened the world; the earth trembled and shook."

Chemistry, in its limited endeavours to reason upon, and to explain the physical cause of a phenomenon so tremendous, discovers by experiment that sudden or extensive changes, either mechanical or chemical, of the form or state of substances, are generally attended by the development of the imponderable agent—electricity.

Frequent mention has been made during this inquiry, that an enormous change of water from the liquid to the vaporous state is incessantly proceeding from every aqueous portion of the globe, and to such change Chemistry refers—with extreme probability—the immediate cause of the thunder-storm, it being discovered that the artificial conversion of water into vapour, always developes electricity, and in some cases, developes it with the striking concomitants of vivid light and snapping sound, differing only in degree from natural lightning and thunder.

Electricity can be artificially excited and accumulated in power and intensity; its spark directed for the fusion and combustion of metals, the paralysis and death of organic bodies, and thus to imitate upon a limited scale the effects of the lightning flash of the boundless heavens.

It is discovered that substances having a redundancy of electricity, or being charged with electricity, invariably endeavour to impart or discharge it to others that are in a deficiency, to restore a natural equilibrium of the ethereal power, and when this is suddenly and extensively effected, it is as invariably attended by the equally ethereal powers of light and heat.

Mention has been made of the fact, that some substances are conductors, others imperfect, and others, again non-conductors of electricity, page 56; it may therefore be remarked, that the greatly desiccated atmosphere of summer, and of the early part of autumn, is an extremely imperfect conducting medium of electricity, and this agent, by some

recondite power—probably incipient condensation of aqueous vapour—accumulates in the clouds, which are conductors on account of their constituent water, floating in the generally desiccated and imperfectly conducting air, or in other words, the watery clouds charged with electricity are sustained by a volume of dry air, which cannot deprive them of their charge.

The clouds therefore seek to discharge their electrical surplus to the solid earth and the flowing waters; the air cannot conduce to their effort; eventually their surplus becomes so excessive, so powerful, so eager of escape, that it suddenly disrupts the air, as a flash of lightning to the earth and waters; it is succeeded by thunder, a sound produced by the instant and violent collapse of the disrupted air to restore its own balance. "Like as when an arrow is shot at a mark, it parteth the air, which immediately cometh together again, so that a man cannot know where it went through."

The flash and the thunder are really simultaneous; the former is instantly seen, as light travels at the rate of 192,000 miles in a second of time, whilst the latter is subsequently heard; as sound only travels 380 yards in a second of time; accordingly the interval that elapses from the moment that the one phenomenon is seen and the other heard, being multiplied by this number, will indicate the distance of the discharge. Thus, if the flash be seen six seconds before the thunder be heard, then $6 \times 380 = 2,280$ yards, or, one mile, two furlongs, and eighty yards, as the distance of the discharge that took place.

Be it particularly remembered, the calculation only regards a discharge of lightning that has taken place, and is no criterion of the absolute safety of the observer, for other discharges may rapidly take place closely around him, as electrical clouds frequently spread above a large extent of terraqueous surface, and two or three flashes may be seen simultaneously at different distances in the atmo-

sphere. When the flash is long, irregular, angular, and gnarled, it announces the disruption of an extensive volume of the atmosphere ; when it is short, regular, straight, and direct, it announces the disruption of a comparatively limited volume of the atmosphere ; in the one case, the flash would be seen several seconds before the thunder would be heard, and in the other, the flash would be instantly followed by the thunder.

The tree represented in the back-ground of the accompanying engraving, is supposed



Fig. 38.

to have determined the discharge of lightning from a cloud hovering at a very considerable altitude, the flash is therefore long, irregular, angular, and gnarled, and a spectator of the storm, if standing near the tree, would first hear the thunder, from the collapse of the air near its summit, then from beyond

it, then from a greater distance, and ultimately from the cloud whence the lightning broke forth ; therefore the thunder would fall upon the ear, as an irregular succession of sounds, producing a loud rumbling noise.

The tree represented in the fore-ground of the engraving is supposed to have determined the discharge of lightning from a cloud hovering at an inconsiderable altitude, the flash is therefore short, regular, straight, and direct, and a spectator of the storm standing near this tree, at the moment of the flash would hear the full thunder of the collapsing air as one loud and terrible crash, which in a few seconds would be reverberated from distant surrounding objects, and ultimately die away in silence.

The peculiar odour prevalent during a thunder-storm is

that of nitric acid, produced by the exciting agency of the lightning upon the oxygen and nitrogen of the volume of the atmosphere disrupted by the flash: the chemist guided by observation, analogy, experiment, and by the all perfect examples of Beneficent design that are displayed throughout the universe, ventures to state that the production of the powerful acid may be destined to aid the commotion of the storm, in destroying and removing the mephitic exhalations that arise from organic matters putrefying in the heat of summer and autumn.

The occurrence of thunder-storms is always dreaded by the husbandman, not only on account of the extreme probability of the lightning striking his homestead and instantly kindling its well-stored harvest in one consuming flame, but also on account of the usual concomitants of sudden and violent showers of hail and rain that burst from the clouds, and so lacerate and prostrate the standing crops, so tear the fruits, and strip the leaves of orchards, that frequently, after the storm has subsided, these fragile organic structures can scarcely, if ever, recover from the disastrous shock to meet the genial rays of the sun, and ripen into the maturity of an autumnal harvest.

The immediate cause of these dread concomitants of the thunder-storm, is hitherto shrouded in impenetrable mystery, no man can "understand the spreadings of the clouds," no man hath "seen the treasures of the hail," but the terrible visitations of these messengers of Divine power, have been experienced by mankind from the earliest ages of the world, for the Scriptures record that "the Lord sent thunder and hail, and the fire ran along the ground."

"He maketh lightnings with rain."

"He destroyed their vines with hail."

"He smote with hail in all the labours of harvest."

"The voice of the Lord breaketh the cedars, yea, the Lord breaketh the cedars of Lebanon."

As in the earliest ages, so at present, the countries of the

East are yet especially subject to the foregoing visitations in a tremendous degree, and England occasionally experiences them in one scarcely inferior.

Crystalline hail-stones, and amorphous masses of ice, three, six, even nine inches in circumference, suddenly shower from the clouds, and devastate not only the corn crops and orchards of open plains and valleys; but exotic flowers and fruits that are sedulously kept in fragile glass conservatories.

The continuance of hail is only a few minutes, but the quantity that falls in so short a time is often enormous, covering the earth to a depth of several inches.

Upon examination of a moderate sized hailstone, received by a soft yielding surface, and thus prevented from shattering by its violent collision with the earth, it will be found to possess the crystalline form of a short six-sided prism, terminated at each end by a short six-sided pyramid, one being invariably truncated.



Fig. 39.

The known phenomena attendant upon the ordinary transition of water into ice will claim our particular attention at a future time.

“The voice of the Lord is upon the waters; the God of glory thundereth; the Lord is upon many waters; the voice of the Lord is powerful; the voice of the Lord is full of majesty.”

In such sublime and rapturous exhortation to the princes of the earth, does the Psalmist set forth the power and might of the Omnipotent Ruler of the storm: no man can either feel or feign indifference towards its awful and astounding grandeur; yet he does well, who, instead of indulging in morbid fear and of communicating it to others, rather endeavours to calm the emotion by sincerely reflecting within himself, and humbly expounding to those around him, that the will of God directs the storm, that in His hand are the lightnings displayed, to direct our thoughts towards the throne of His power and mercy, to remind us of

the frailty and uncertain tenure of our being, which, in the fulness of our abundance, and the pride of our knowledge, we are but too prone to forget. It is however the bounden duty of man to exercise his reasoning and inventive faculties to the utmost for humanly guarding his own life, and the lives of others, against the physical power of the lightning, and not with presumptuous impiety to defy the storm, in the hope that the uneducated and credulous may call him a philosopher; thus his vanity would be gratified, but his conscience would be outraged, and would reproach him as being unworthy of the distinguished title, which—as its derivation imports—appertains to those who are lovers of wisdom, and who diligently search for it throughout the wondrous works of God; not to those who regard them with a contemptuous indifference, either real or feigned.

The terms “philosopher” and “philosophy,” are so constantly misapplied at the present day, that the student of natural phenomena is imperatively called upon to remember the Apostolic warning—

“Let no man spoil you through philosophy.”

But returning from this slight digression to the immediate subject of inquiry, the protection of life from lightning:—in the open air, shelter should not be sought immediately under a tree or a building, for should they be struck, such situations are particularly dangerous, if not fatal; the distance of twenty or thirty feet from tall trees or lofty buildings is, on the contrary, an eligible situation; for should a discharge take place, these prominent bodies are most likely to receive it, and the less elevated bodies in their vicinity may therefore escape uninjured.

“It is quite essential during a thunder-storm, to avoid every considerable bulk of water, and even the streamlets that may have resulted from a recent shower, for these are all conductors, and the height of a human being when near them, might probably determine the discharge of lightning:

shelter under the arch of a bridge is a comparatively safe situation."

"The conductors and imperfect conductors by which lightning enters when it strikes a building, are generally the metallic appendages of the walls and partitions; the most secure situation is therefore in the middle of a room, especially when standing on a hair mattress, or even a thick hearth-rug, and if a bed be drawn into the middle of a room it will afford perhaps the safest of all situations."

The part of every building least likely to receive injury is the middle story, as the lightning does not invariably pass from the clouds to the earth, but occasionally from the earth to the clouds,—a phenomenon called the returning stroke—hence it is useless to take refuge in the lowest story or in a cellar; many instances are recorded in which the basement has been the only part of a building that has sustained severe injury, the lightning being weakened as it ascended.

Whatever situation be chosen, any approach to the fire-place is most dangerous, for the heated air or even the soot in the chimney, are conductors sufficiently good to determine the course of the lightning flash, especially as they are in immediate connexion with the excellent conducting iron work of the grate, fender, and fire-irons; the same caution is necessary with respect to gilt furniture cornices, bell-wires, and moderately extensive metallic surfaces of every description. It is likewise exceedingly dangerous to approach a window for the purpose of closing its shutters, if they have large iron bars or bolts for fastenings; an instance is known of a shock having been suddenly experienced by a person whilst endeavouring to bar a window shutter during a severe discharge of lightning; the effect lasted for some hours, but providentially did not prove fatal; in a carriage, the precaution of keeping at some inches distant from its sides or back is also desirable.

"These particulars have been enumerated from a desire

to supply what useful information the present state of our knowledge may afford, and to diminish that anxiety and fear by which the minds of many are oppressed during the occurrence of these magnificent but awful phenomena."

"Where persons have been killed by lightning, it has generally come upon them so suddenly as to leave no time for precaution, though it must be admitted that some have suffered from foolishly ridiculing the idea of danger, and wantonly exposing themselves to the storm, walking out to admire its grandeur, or insisting upon opening the windows to look out and observe it, or standing under a tree for shelter."

"A severe thunder-storm is always an awful and dangerous phenomenon; and while, on the one hand, it is the extreme of folly to neglect common precaution, or to ridicule those that are alarmed, it is on the other, equally weak to give way to unfounded apprehension."

The astonishing discovery of the identity of lightning with electricity was made by the use of a common kite, and it proves that men must condescend to attend to the most ordinary things if they would acquire knowledge, for the design of philosophy is "not to build a capital or erect a pyramid to the glory of man, but to found the temple of the universe in the human intellect."

At a very early period of scientific research, experiment had shown that electricity is attracted by metallic points, and, if highly excited, discharges itself with a flash and report; lightning and thunder exhibited an example of a flash and report, the atmosphere was known to be susceptible of electrical influence, all this had been ascertained, but no relation had been established between the cases; other causes might possibly produce a flash and report; but the analogy of electricity presented itself strongly to the mind of a philosopher who reasoned as follows:—"The electric fluid is attracted by metallic points: we do not know whether this property be in lightning, but since they agree in all particulars in which we can already compare them, it is not impro-

hable that they likewise agree in this; let the experiment be made."

He made the experiment by attaching a pointed wire to the stick of a kite, and upon elevating it in the air during a thunder-storm; as the string became wetted with rain, it conducted electricity from the clouds, which, on its arrival at the ground, was regularly discharged with vivid sparks and sharp reports, and the analogy converted into an identity.

This true philosopher was overcome with emotions of awe at the wonderful discovery that the Almighty had thus vouchsafed him permission to make regarding the astounding phenomena of the lightning clouds; and as the whole of his previous life had been devoted to the humble pursuit of science, and in endeavours to cause its principles to "enrich human life with useful arts and inventions," he immediately sought to apply this discovery to the protection of dwellings from the terrific effects of lightning, by elevating upon them pointed metallic rods in deep connexion with the humid earth, and thus affording ready and continuous paths for the passage of the natural electricity of the charged clouds.

Accordingly, rods of iron, copper, or zincd iron, the latter being preferable on account of its durability and cheapness, are attached to buildings as good conductors, for preventing the lightning discharging itself and exerting its destructive power upon the imperfect conductors presented by stone, brick, and wood-work.

The accompanying engraving represents a building fitted with a lightning-conductor, and its construction may be probably understood from the following description:—

On the summit of the spire or roof, the zincd iron bar is firmly fixed; it is two inches square at its base, it tapers gradually upwards to a height of twelve or fourteen feet, and terminates in a sharp point; the base of the bar is made two inches square, that it may not be materially swayed from the

perpendicular by the force of storms; and to prevent rain from being attracted by its means amidst the stone-work or wood-work of the spire or roof, which would cause decay, the square bar is provided, just above its base, with a conical cap of its own metal, spreading six or eight inches all around, which will effectually cast away all rain-drops from the part of the spire or roof to which the bar is fastened.



Fig. 40.

Immediately above this conical cap, a zincd iron bar, two inches square, and of any suitable length, is firmly fixed to project horizontally as an arm, and to its extremity a zincd iron bar, one inch square, is united, and then this proceeds in the same slope as the spire or roof, though supported at one foot distant by several zincd iron stanchions, until it reach the eaves, where it is bent, if necessary, to suit the curves or angles of the structure, it then proceeds downwards in a line parallel with the wall, though still kept at one foot distant by zincd iron stanchions, until it reach the base of the structure.

At this spot the zincd iron bar is bent and adjusted either horizontally or in a sloping position, to enter a trench in the ground, two or three feet deep, extending from the base of the structure to the nearest collection of water or extremely damp soil, the bar being laid in the centre of the trench which is then filled with earth, and the extremity next the water, being fitted with three or four points of zincd iron, is then sunk therein to a depth equal to the height that the pointed extremity of the tapering bar projects into the atmosphere.

The lightning conductor is thus completed, and upon the approach of clouds charged with electricity its point will gradually attract the subtile agent, and silently and safely conduct it to the water or humid soil, and thus restore an equilibrium of electrical state that otherwise might have been effected by the lightning suddenly and violently striking and damaging the structure.

Although the conductor is supported at intervals by zincd iron stanchions projecting from the stone or brick work of the structure, these will not divert the electricity from the conductor, for electricity always seeks the most direct course that can be proffered, and will not quit it for any other.

Ships are protected by conductors generally made of copper bars attached to their masts, and carried down into connexion with the water, and by such contrivances much fearful damage from lightning has been prevented.

Electricity and Chemistry—for the sciences are intimately connected, the chief evolution of electricity being dependent upon chemical action,—lead to the conclusion, that in certain states of the atmosphere, although a cloud may not be so powerfully charged with electricity as to seek a restoration of its equilibrium by a disruptive flash of lightning to subjacent objects, it may be sufficiently charged when at a moderate elevation that its own entire and mobile volume of aqueous particles will yield downwards in the form of a watery column, through which the inherent electricity will seek a rapid though silent discharge; the same—to use a very humble, yet not unapt simile, for conveying an idea of the mere attraction and transit—as a large lock of cotton, nearly saturated with water, when held in one hand, may have some of its filaments drawn out by the other in an unbroken form, through which by capillary attraction the water will pass in a smooth unbroken stream until its excess have drained away.

An electrical cloud, when thus yielding to the attractive or inductive power of the objects over which it hovers, is gradually drawn from its rounded and swelling form into that of a fringe, and this gradually tapers into the form of a well defined point; then as the distance between the cloud and subjacent objects diminishes, this point becomes more and more elongated until at length it forms an unbroken conductor not only for the discharge of the electricity of the cloud, but likewise for a torrent of its water; and these phenomena having ensued, the cloud either disappears, or presents but a miniature semblance of its original form.

This natural phenomenon is popularly known as "the water-spout," and generally speaking its electricity is not so much to be dreaded as the vast aqueous torrent that descends with impetuous force upon the dwellings of man, and the labours of the field, which are alike overthrown and deluged by the sudden and concentrated inundation.

The occurrence of the water-spout is by no means so common inland, as at sea, and there it displays itself in a yet more remarkable manner, for in place of the solid and fixed earth, the liquid and flowing water presents an attractive surface to the floating and mobile vapour of the electric cloud. Then not only does the electric cloud emit an elongated portion of its volume as the precursor of its full descent, but the level surface of the water simultaneously rises as a pointed wave, and thus by mutual attraction, the former continuing to descend, and the latter to ascend, they at length suddenly coalesce and form an aqueous conductor for the restoration of the electrical equilibrium: and this being effected, the water of the cloud is ultimately received into the bosom of the ocean, from whence it was originally exalted to the cloud by the influence of the imponderable agency of atmospheric heat.

An idea of the form of this remarkable, and doubtless important phenomenon, may be gained by reference to the accompanying engraving.

It has been discovered that a sudden and violent concussion of the atmosphere, will frequently cause the descending cloud to burst before its union with the ascending wave, and accordingly mariners are in the habit of discharging a shotted gun in its direction, that the shot may strike, and the concussion of the air impinge, upon the cloud, and thus avert the probability of the water-spout extending and engulfing their valued ship.

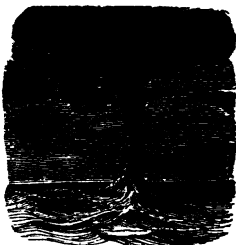


Fig. 41.

A large, stately, firm structure the ship may be, in comparison with the hands by which it was fashioned, but it is a small, lowly, and frail shell in comparison with the vast, magnificent, and powerful flood of water upon which it floats ; it bears not so great a proportion to the ocean as the smallest grain of sand bears to the largest artificial globe ; and therefore instead of considering it as extraordinary that shipwrecks so frequently occur, it should rather excite our astonishment, that in vessels so minute, mariners have been permitted by the Almighty to circumnavigate and ascertain the boundaries of the gigantic world which He hath created, and so miraculously preserves, throughout its unerring orbit, around the million times more gigantic sun.

“ They that go down to the sea in ships, that do business in great waters ;

“ These see the works of the Lord, and His wonders in the deep.”

Thus, in addition to the wonderful phenomena of constant occurrence, as thunder-storm, water-spout, tempest, hurricane, and wave, mariners sometimes behold with astonishment and awe, fiery volcanoes suddenly bursting forth from the depths of the ocean, attended by lightnings, red hot lava, boiling mud, clouds of steam, electric

columns of water, and the incandescent scorix of the eruption ultimately cooling and forming an island of considerable extent; all these phenomena, so far as man is permitted to discover, being caused by the abrupt, violent and extensive chemical changes which matter is commanded to sustain by "the Creator of the heavens and the earth, the sea, and all that in them is."

We have found the earth capable of absorbing heat, though incapable of conducting it to any considerable extent; we have to discover how the earth parts with an excess of heat by radiation to the heavens.

The meaning of the term radiation may be thus explained:—suppose the circle in the centre of the annexed engraving to denote a heated body, the right lines emanating from its circumference may denote rays of heat, escaping or radiating from it in all directions into the atmosphere, quite independent of either conduction or convection.



Fig. 42.

A few simple experiments of the chemical laboratory will serve as introductory to the grand natural phenomenon of terrestrial radiation.

A plate of metal, either dull or bright, is an excellent conductor of heat; and if a lighted coal be placed upon any part of its surface, the metal will commence to conduct the heat in all directions throughout its mass.

At the distance of four or five feet in front of a clear glowing fire, hold a large bright tin-plate, turn it about, present its bright surface at different angles to the fire; at length a certain angle will be found at which the plate will remain cold, but heat will dart from its surface, and will be powerfully felt upon the face or hands.

Thus, in chemical language, heat is said to radiate from

the glowing fire, to pass through the intervening non-conducting air, and to impinge upon the surface of the metal plate: although it is an excellent conductor of mere heat of contact, as that of the lighted coal, it is not a conductor, it is not an absorber, it is not a retainer, of the radiant heat that reaches it from the distant fire, but it is an admirable reflector of that imponderable agent, rays of which, as they impinge upon its surface, are instantly bent back or reflected therefrom to surrounding objects, whilst the surface itself acquires no elevation of temperature, page 54.

Place the bright tin-plate flat upon a table, fold half a sheet of fine emery paper smoothly around a small book or a flat piece of cork, and with the emery paper rub the surface of the plate all over in the direction of its length, then do the same in that of its breadth, and thus effectually destroy all brightness or polish.

Now hold the tin-plate with its roughened surface towards the fire, at the same distance as at first, it will reflect but little heat upon the face or hands, but it will become heated; thus by mechanical alteration of its mere surface, the metal is deprived of its original power of reflecting such agent, and rendered a receiver or absorber of radiant heat, which is then conducted by the metal throughout its whole extent.

Select another tin-plate, brush over one of its surfaces with weak glue, then sift fine sand upon this, and allow it to dry: by this proceeding the metallic polish is only covered, and not destroyed, and upon holding this sanded surface towards the fire, as already directed, it will reflect very little heat, but will become very hot.

Similar will be the result if the tin-plate be painted with a mixture of weak glue and lampblack, whiting, yellow ochre, chrome-yellow, vermilion, blue-verditter, orange-chrome, mineral-green, or any of the substances commonly known as "colours."

The following experiments will afford striking illustra-

tions concerning the extraordinary manner in which the mere alteration of a metallic surface affects its habitudes with radiant heat.

Select a large tin-plate, equally bright and polished upon both sides; with a strong pair of scissors or small shears cut it across to form two pieces similar in size; leave one of these without any further preparation, but paint one side of the other with lampblack mixed with thin glue, and allow it to dry; provide a lath of wood one foot long, one inch and a half thick, and four inches wide; with a saw make two cuts or grooves across this, each of them being an inch from each of the ends of the wood, and each sufficiently deep to hold a tin-plate firm and upright, when inserted therein on its shortest edge.

Place each plate in its groove, the black surface of the one opposed to the bright surface of the other, attach a marble to the centre of the exterior surface of each with a small lump of pomatum, then hold a red hot iron-heater exactly between the plates, as shown in the annexed engraving.

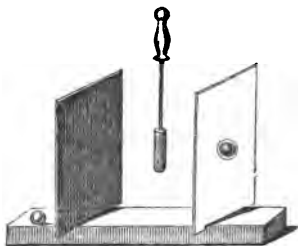


Fig. 43.

Thus the plates will be similarly exposed to the heat that is radiating from the red-hot iron, but the bright surface will reflect nearly all that impinges upon it, and will not become hot enough to melt the pomatum, so the marble will continue to adhere, whilst the black surface will absorb nearly all that impinges upon it, and will quickly become hot enough to melt the pomatum, and cause the marble to drop.

Chemistry proves by accurate experiments, that as the unmetallic surface will absorb radiant heat with the most

facility, so will it part with such heat with the most facility; this fact may be illustrated by a very simple arrangement of apparatus.

Provide two cylindrical canisters of tin-plate, each of these being six inches in height, two inches and a half in diameter, and having a cover with a knob in its centre, and a circular perforation near that, about three-quarters of an inch in diameter; the covers must fit tightly, or have small catches, so that upon holding them by their knobs the canisters will not fall away, but will require considerable force for their separation.

Polish the exterior of one of the canisters as bright as possible, paint the exterior of the other with the black mixture as described; when dry, fill it with cold water, then fill the other with cold water; take the thermometers that were used in a former experiment, page 157, cleanse the bulb of the one from adhering oil, by washing it with a solution of pearlash, then rinse it with water, pass it through the circular aperture of one canister to dip into the water; and do likewise with the bulb of the other thermometer and the other canister.

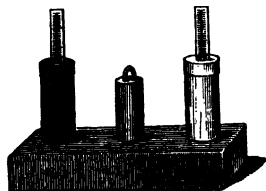


Fig. 44.

In the centre of a soft brick, laid flat, with a knife or chisel make a circular hole about three-quarters of an inch deep and sufficiently large to admit the end of the iron-heater of a tea-urn, make the heater red-hot, then with a hook drop it into the hole, and place a canister to stand at each end of the brick.

The canisters are thus equi-distant from the radiant heat of the iron—indeed more accurately so than the tin-plates were in the last experiment—still the blackened surface will gain heat faster than the polished surface, and conduct

such heat faster to the water, as an inspection of the thermometers will prove.

Let it heat to 100° —using a fresh heater, if necessary—then remove the canister from the brick, place it upon a table; remove the bright canister also, throw away its comparatively cold water, refill it with water heated to the same degree as that in the black canister, place it likewise on the table two or three feet distant from the other, insert the thermometers, watch them, and they will detect the black canister to be radiating the heat that it had absorbed and conducted to the water, with more rapidity than the bright canister is radiating the heat communicated to it by the water that was introduced; or, in other words, when the water in the black canister has become cold, that in the bright canister will remain warm.

These experimental results are directly contrary to all anticipation; for it might be reasonably imagined that by coating the metal with black paint—carbon being a bad conductor—it would prevent the heat from contact with the metal beneath, and so keep it cool; and in the other case, that the coating of black paint would prevent the heat of the water from escaping, and so keep it warm; but Chemistry proves that unmetallic substances, as carbon, and earthy substances, as whiting and ochre, although extremely bad conductors, are most excellent absorbers and radiators of heat.

As regards terrestrial radiant heat—meaning that of an ordinary fire or other artificial source of heat—the chemist discovers that surfaces, if similar in mechanical texture, may differ in colour without having either their receptive or their emissive radiating power increased or diminished: on the other hand, with solar radiant heat, the colours of such surfaces do most strangely affect both these powers, for dark colours absorb and radiate more rapidly than light colours; and black—the absence of colour—will absorb and radiate more rapidly than white, the presence of colour.

On account of this powerful absorption of solar heat, by blackened surfaces, the iron bar employed in the experiment described at page 141, was placed on the top of a black hat, that it might become more intensely heated than it would have become on any other surface; and if the flasks employed in the experiments described at pages 142-6, be now painted black, and exposed to the sunshine, they will heat with greater rapidity; and when removed to the shade they will cool with greater rapidity than they did when their surfaces were uncovered.

Procure nine pieces of kerseymere cloth, alike in size and texture, but different in dye, each of the first seven having one of the prismatic colours, and of the remaining two, one being black, the other white; let all these pieces of cloth be spread out and exposed in an equal degree to the sunshine, and the bulb of a thermometer applied to them successively from time to time, it will indicate that they do not heat with equal rapidity; but probably in the following order, the first colour being the hottest, violet, indigo, blue, green, red, orange, and yellow; the black cloth, however, will surpass even the violet in temperature, whilst the white cloth will not attain even the temperature of the yellow.

From an experiment of this kind, we discover that the "warmth or coolness of clothing, depends as well on its colour as its quality; a white dress, or one of a light colour, will always be cooler than one of the same quality, black, or of a dark colour, and especially so in clear weather, where there is much sunshine; white or presence of colour, and very light hues, reflect heat copiously: but black or absence of colour, and very dark hues, reflect but little; experience has long supplied the place of science in directing the choice of clothing; the use of light colours always prevails in summer, and that of dark colours in winter."

Reasoning upon the facts disclosed regarding the powerful absorption of heat by black and dark surfaces, it might be

concluded that the black skin of the Ethiopian, would cause him to undergo severe sufferings from the intensity of the tropical solar rays; but our experiments be it remembered have been made either upon inorganic matters, or upon organic matters deprived of vitality, and their results do not hold good with bodies under the direct influence of the recondite agencies of life; an extraordinary fact, or anomaly,—so called by the finite wisdom of man—is then presented, for Omnipotence has ordained that the skin of the Ethiopian shall absorb heat powerfully, and at the same time that it shall not sustain the slightest injury.

This extraordinary fact was originally investigated by a physiologist in a series of simple yet decisive experiments of which the following are selected:—

During an intensely hot day, he exposed the back of each hand to the sunshine for ten minutes, one hand being bare, and having a thermometer attached to it; the other being covered with black cloth, and beneath this the bulb of a thermometer.

At the expiration of the above time, the exposed thermometer indicated 85°, whilst the covered thermometer indicated 91°; in a second trial the former indicated 91°, the latter indicated 94°, and in a third trial the first thermometer indicated 98°, whilst the second indicated 106°.

In these three trials, the bare skin was powerfully scorched and raised in blisters, but the covered skin, though so much hotter, was not in the slightest degree injured.

Upon covering one hand with white cloth, and the other with black cloth, and exposing them for a similar time to sunshine, the former was invariably scorched, but the latter never affected.

The power of the solar rays to scorch the skin of man is destroyed when the surface is black, although the absolute heat, in consequence of the absorption of the rays is greater! the fact is incontrovertible, but has not been satisfactorily explained, and therefore it is much better at present to re-

gard it as a curious anomaly than to theorize upon its cause.

"The same wise Providence which has given so extraordinary a provision to the negro for the defence of his skin, while living within the tropics, has extended it to the bottom of the eye, which otherwise would suffer in a greater or less degree when exposed to strong light; the retina from its transparency allowing it to pass through without injury."

The black or dark matter of the retina is technically called the *nigrum pigmentum*, "and is probably not absolutely necessary for vision, but only provided as a defence against strong light, since it is found to be much darker in the Ethiopian than in the European, and is of a lighter colour in fair people than in dark, and therefore lightest in those countries farthest removed from the effects of the sun."

The sudden and fatal infliction, called the sun-stroke, that frequently prostrates reapers and labourers in the intense heat of harvest time, is referred to the scorching power of the solar rays upon the scalp of the head producing inflammation of the brain; this dreadful calamity, is recorded with exquisite simplicity, and touching pathos in the inimitable language of Scripture:—

"And when the child was grown, it fell on a day that he went out to his father to the reapers. And he said unto his father, My head, my head. And he said to a lad, Carry him to his mother. And when he had taken him, and brought him to his mother, he sat on her knees till noon, and then died."

In extremely hot climates the traveller is often sun-stricken and dies; and in allusion to the watchful care of Providence over His chosen people, Scripture declares, "They shall not hunger nor thirst; neither shall the heat, nor the sun, smite them; for He that hath mercy on them, shall lead them, even by the springs of water shall He guide them."

The difference between the heating of dark and light

coloured soils, when equally exposed to solar heat, and their difference in cooling when equally placed in the shade,—mentioned at page 156, may be now stated in technical language, viz. that dark soils absorb heat more powerfully, and radiate heat more energetically than light coloured soils which reflect a great portion of heat.

Take the thermometers employed in the experiment at page 206, paint the bulb of the one with the black mixture as at page 205, and that of the other with a mixture of whiting and glue of equal thickness with the black; let the bulbs dry, then expose the thermometers simultaneously to the sunshine; it will be found that the black bulb absorbs heat quicker than the white bulb, by the quicker rise of the mercury in its tube; and then upon removing the thermometers into the shade, the black bulb will indicate that it radiates heat quicker than the white bulb, by the more rapid descent of the mercury in its tube.

The science of Astronomy proves the gigantic sun to be the glowing centre of light and heat, around which the planetary bodies perpetually revolve in unerring orbits as when in the beginning liberated from the hand of the Creator.

Heat emanates from the sun, is received and absorbed by the solid earth, communicated from it to the atmosphere, and transferred from the atmosphere to the ocean, and, in consequence of the rotation of the globe on its axis and its inclined position in its orbit, the northern and southern hemispheres are alternately subjected more directly to the influence of the solar beams than they could have been without this excellent and admirable adjustment; thus the elevated temperature of the equatorial regions is moderated, and a general diffusion of warmth ensues.

The solar beams are powerful in proportion as they impinge upon the earth in a vertical position, and if they never deviated from such direct and piercing line, the heat of the equatorial regions would be yet more intense than it

is already, and the oblique beams in northern latitudes would be too feeble for the communication of heat and light sufficient for the growth and maturity of vegetable productions, nor would the beautiful and beneficial phenomena of the change of seasons be presented for our earnest admiration and grateful appreciation.

Then the water of the ocean, on account of its non-conducting power, slowly absorbs, but eventually accumulates within its liquid depths an enormous amount of specific heat, which imponderable store cannot escape by radiation from the surface, as its liquid form is unfitted for that phenomenon to ensue: thus the ocean cannot cool rapidly like the earth, during the absence of the sun from any given locality of its surface, but can only become lowered in temperature, and that even slowly, by imparting heat to the atmosphere in actual contact with its waves.

Thus, in warm seasons, the ocean abstracts heat from the atmosphere, and in cold seasons imparts heat to the atmosphere, and consequently tends to a mitigation or equalization of temperature, of both the water and the land, which phenomena have most important relations to the welfare of the animal and vegetable creation.

The limit prescribed for this general investigation concerning the principal phenomena of the four seasons which admit of elucidation by the science of Chemistry, demands the conclusion of these remarks relating to a few only which are presented during the beautiful season of Summer, and whilst attentively considering and humbly endeavouring to explain the "wondrous works" by which we are surrounded, we have been inevitably led to extol the power and beneficence of the Almighty.

"He that created the heavens and stretched them out; He that spread forth the earth, and that which cometh out of it; He that giveth breath unto the people upon it, and spirit to them that walk therein."

CHAPTER III.

Autumn.

"He changeth the times and the seasons;" He now ordains the reign of Autumn to commence, the glorious sun still shedding brilliancy and heat for the advancement of the productions of the earth to the mature and bounteous harvest, the hope of which has so long cheered the husbandman throughout his anxious toils.

Many extraordinary and beneficial phenomena are frequently presented in so equal a degree during the end of Summer and the beginning of Autumn, that it is difficult to decide unto which season they belong, so insensibly do they merge into each other; we may therefore continue our investigation concerning the miraculous provision that is made by the power and goodness of God, to prevent the earth from accumulating a withering and destructive intensity of heat, and this will gradually lead the way to other phenomena which are popularly recognized as being autumnal.

The night was serene, the moon and stars shone, no clouds gathered, no rain descended; we step forth at dawn and find the grass and the flowers of the field thickly

studded with myriads of aqueous drops, sparkling like diamonds in the golden rays of the rising sun.

This refreshing gift we gratefully acknowledge as "the dew of heaven," although we may not immediately understand the mystery of its gentle and silent deposition upon the productions of the earth, during the serenity and radiance of the Summer or Autumn night; we are therefore led to inquire if the phenomenon can receive interpretation from Chemistry.

It can—and the interpretation will furnish another proof of the power and goodness of God, for "His favour is as dew upon the grass;" another proof of the ever-watchful care of Him to whom "the darkness and the light are both alike;" whose Hand is equally extended for the protection of the animated creation, during its noon-tide activity and its midnight repose. Chemistry unfolds the fact, that throughout the fervent glow of a summer or autumn day the solid opaque earth absorbs heat, which chiefly abides at, or near its surface, and is not conducted to any remarkable extent beneath; but at sunset, if the atmosphere be cloudless and calm, the earth immediately commences to radiate part of its heat upwards, and by so doing, becomes many degrees colder than the air directly incumbent upon its surface; accordingly the aqueous vapour, invisibly present in the still warm air, is chilled or condensed by contact with the cool earth into drops of water, and these "distil as the dew" for the refreshment of its productions.

Examine a garden immediately after sunrise at this season, very probably the grass-plat will be found saturated with dew, the gravel walk nearly dry, the hollyhock dripping with water, the laurel free from moisture, all these objects were similarly exposed to the night air, and if dew were a fine rain—as it is often imagined to be—all should be equally covered with its drops, and this remarkable difference should not exist.

Chemistry proves the difference to exist, because the sur

faces of the various objects are unlike in their radiating power; the grass-plot and the hollyhock are excellent radiators, they throw off heat with rapidity, and become so lowered in temperature as to induce a more copious condensation and deposition of water from the surrounding air upon their surfaces than the gravel walk and the laurel, which, being bad radiators, retain heat, and remain so warm that the aqueous vapour in the air wafts over their surfaces without being chilled or condensed, and therefore they are nearly free from dew.

Rough or woolly leaves—like the painted or sanded surface of the tin plate, page 204—radiate heat with rapidity, whilst smooth or varnished leaves—like the polished or bright surface of the tin plate, page 203—do not radiate with rapidity: therefore the former leaves ensure a more plentiful deposition of dew than the latter.

From the limits of the garden, let us carry forth these observations and experiments into the boundless universe, and discover the miraculous workings of Providence.

Barren rocks and soils, by reason of their peculiar hard and compact structure, have neither the power of absorbing nor of radiating heat with great energy; they do not speedily acquire a low temperature during the clear nights of summer and autumn, and, as a consequence, dew is scarcely deposited upon them; it is not needed for the welfare of their inorganic structure, and they have no vegetable life, or but little of the lowest grade to maintain.

Naturally fertile soils, and such as are artificially rendered productive, are generally of loose porous structure; this physical peculiarity enables them to absorb heat energetically during the day, and to radiate a portion of it rapidly at night, and thus become so many degrees colder than the ambient air, that its aqueous vapour condenses upon them and their productions as dew in abundance.

Thus the "precious dew of heaven" is not lavished upon objects unfitted for its reception, and which can derive no

benefit from its genial influence, whilst it is abundantly deposited upon such as are properly prepared, and accordingly those "bring forth good fruit," whilst the others remain as barren stones. It is indeed a subject well calculated to arrest our attention, and excite our admiration and gratitude, when we thus find every soil, plant, shrub, and tree, has by its own inherent physical peculiarity of structure, induced the deposition of dew in proportion to its wants; and when we reflect that not a single dew-drop is created in vain, but each is measured by the Hand of Infinite Wisdom, and appointed to fulfil some useful end.

Some tracts of vegetation radiate heat with such vast energy, that the low temperature they attain, not only causes the plentiful deposition of dew, but subsequently changes its diamond drops into pearls of frost; and this extreme of cold, if continued, would be equally fatal to vegetable life as an extreme of heat.

As upon a former occasion, page 173, we discovered the Hand of Providence extending clouds to veil the earth from the scorching heat of noon; so upon this, do we discover the same Hand extending clouds to shield the earth from the chilling radiance of night: "For His mercy is great above the heavens, and His truth reacheth unto the clouds."

These recondite accumulations of aqueous form, intervening between the earth and the confines of the atmosphere, act as opaque screens in arresting radiation of heat from the earth to the heavens; and being warmer than the earth, they radiate part of their own heat downwards to it, and thus restore a genial temperature to its chilled productions.

Tranquillity of the air, and clearness of the sky, are essential to the perfect deposition of dew; very little ensues during the prevalence of winds, none during that of clouds, —unless they are exceedingly high—because the former disturb, and the latter arrest, the radiation of heat from the earth.

The following simple and instructive experiments regarding the beautiful phenomenon of the deposition of dew, can be readily performed during a fine summer or autumn night.

For example, weigh some dry wool into two portions of twenty grains each, bend a large sheet of stout pasteboard in half, to form a kind of pent-house; place this with its ridge uppermost on a closely mown grass-plat—away from any building—lay one of the portions of wool on the middle of the grass beneath the pent-house, and the other portion on the adjacent grass fully exposed to the sky.



Fig. 45.

Examine the arrangement at sunrise; the portion of sheltered wool will probably be found increased only four or five grains in weight, whilst the exposed portion will be found increased about thirty-two or thirty-four grains in weight; the slight pent-house, although open at both ends, and admitting the free access of air, preventing the direct radiation of heat from the wool, and accordingly opposing any great deposition of dew; in fact, throughout the night, it has been warmer beneath the pent-house than in the open air.

The experiment admits of variation, to prove that even mere partial shelter from direct radiation, will cause the deposition of dew in smaller quantity than appears upon objects fully exposed, and will entirely remove the notion that dew is a kind of fine rain falling indiscriminately upon the earth from the lofty regions of the atmosphere.

Place a few dry bricks upon a grass-plat to form a small wall about three feet in height, at the foot of this spread a lock of dry wool weighing twenty grains, and at some feet distant, place another lock of similar weight; let this arrangement remain during the night; examine it next morn-

ing at sunrise—always providing that no rain have fallen—the partially sheltered wool will probably be found increased only a few grains in weight, whilst the fully exposed portion will be found increased eight or ten times as many grains in weight.



Fig. 46.

Gravel walks and stone pavements radiate heat, and acquire dew less readily than grass-plats; wool placed on the former has its temperature less depressed than on the latter, and therefore obtains less dew; this effect is by no means referrible to the capillary attraction of the fibres of the wool, for it ensues equally well if the wool be placed in a clean dry saucer, nor is it referrible to hygroscopic attraction of water from the air, because wool placed upon a board at an elevation of several feet from the surface of the earth or grass, during a cloudy night, will not materially augment in weight; the deposition of dew is entirely dependent upon the radiating power of surfaces freely exposed to a clear nocturnal atmosphere. Before Chemistry discovered the cause of dew, all scientific inquirers were at fault to account for the principle upon which a thin mat, employed by gardeners for covering tender plants, protected them from cold; it appeared scarcely possible that a covering so slight, could have any material effect in preventing them from attaining the temperature of the external air, yet common experience proved its efficacy and utility in this respect.

When it was discovered that bodies on the surface of the earth became much colder than the atmosphere, by radiating their excess of heat during a serene unclouded summer or autumn night, the true principle of the gardener's homely practice of covering tender plants with matting, was fully

evident; it prevents plants from radiating their excess of heat, and becoming chilled by a deposition of dew.

To acquire precise information upon the subject, the following arrangement may be made; fix four small sticks upright in the earth of a grass-plot, to form the corners of a square whose sides are about two feet long, and over their upper ends, which are to be about six inches from its surface, tightly draw, and fasten at its corners, a very thin cambric handkerchief, place one thermometer on the grass beneath its shelter, and another on the exposed grass at a few feet distant.



Fig. 47.

In this arrangement there exists no impediment to the free passage of air from the exposed to the sheltered grass, excepting the four small sticks, and there is no substance to radiate downwards to the latter grass, except the fragile cambric handkerchief. The thermometer, however, will indicate the temperature of the sheltered grass to be nearly that of the air, whilst the other thermometer on the unsheltered grass will indicate its temperature 5° less, or colder—and upon one occasion when the experiment was tried, the temperature of the sheltered grass was only 3° , whilst that of the unsheltered was 11° , below the temperature of the surrounding atmosphere; hence we learn the power of an awning infinitely more slight in texture than matting, in averting or lessening the coldness that would otherwise occur and be injurious to vegetation.

For this reason, also, a tent, although constructed of thin canvass, and by no means air-tight, becomes a comparatively warm shelter during a cold night; no dew will be found upon the plot of turf shielded by the tent, but abundance

upon that around the external circumference of its curtains.

Matting that has covered a plant during an autumn night will be found copiously bedewed in the morning and the plant quite dry; the matting—consisting of lignin or woody-fibre—having presented its radiating surface, and parted with its own heat, which otherwise the tender plant would have been compelled to do; nay, occasionally towards the end of autumn, the matting performs this kindly office with such energy that its surface becomes covered with hoar-frost, from which it suffers no injury, as it is dead organic matter, whilst it shields the living organic structure, that otherwise would be summoned to radiate, and so perish at the degree of cold induced by its own power.

In some countries the temperature never falls to 32° , yet ice may be procured by taking advantage of the radiation of heat from surfaces; thus a layer of dry straw or stubble is spread in an open situation during a calm and cloudless night; upon this surface are placed shallow earthen pans filled with water; radiation immediately commences from the straw, which loses heat so rapidly and effectually, and deprives the water of such an amount of heat, that it can no longer remain liquid, and therefore becomes covered with a thin crust of ice.

It has been stated, page 183, that the presence of adventitious water hastens the putrefaction of dead vegetable substances; the same remark is applicable to those of animal origin; in warm climates, more especially, the deposition of water, in the form of dew upon these, induces their rapid putrefaction; and as this generally happens during clear, bright nights, it was anciently supposed that moonlight favoured corruption. The moon, when at full, reflects upon the earth only about one three hundredth thousandth part of the light of the sun; the lunar rays even when concentrated by a powerful lens, and the focus directed upon the bulb of a delicate thermometer do not affect its temperature in the

slightest degree ; hence the phrase—"the pale cold moon" is not only poetically beautiful, but philosophically correct.

The mere light of the moon will not induce putrefaction, and as there is no appreciable heat, the phenomenon appears to be exclusively referrible to the radiating power of animal substances, inducing a copious deposition of dew upon their surfaces, for the presence of water is essentially requisite in all cases of putrefactive changes, and owing to it, organic manure becomes soluble, and fit for absorption by the plants of the soil in which it is present.

If one thermometer be placed upon a grass-plot, and another suspended above, at the top of a stick, three or four feet long, the former will frequently indicate a temperature 15° or 20° colder than the latter ; thus proving radiation to be proceeding with extreme rapidity from the solid soil and its vegetable matter, but not from the ambient atmosphere.

Accordingly the lower volume of air becomes much colder than the loftier volume, and is compelled to relinquish its aqueous vapour as dew ; and if a volume of air over a given locality remain tranquil for some hours, the phenomenon of dew will solely ensue from its lowest and coldest portions.

Thus a volume of air, which fills small valleys and hollow ways, frequently remains undisturbed for many hours ; and although they appear to be sheltered situations, they are often more subject to reduction of temperature than high and apparently bleak situations ; therefore—much to our surprise—we find delicate plants chilled, or even frost-bitten in hollows, whilst others suffer no injury upon the summits of the adjacent slopes. The deposition of dew is not often observed in the narrow and sheltered streets of large towns and cities, because a mutual radiation and interchange of heat then ensues between the buildings and other solid objects, which preserves their temperature nearly uniform with that of the circumambient atmosphere, and it will only de-

posit dew when its temperature falls below its point of saturation with aqueous vapour.

At sunrise during summer or autumn, we frequently see a dense white mist, only a few feet in height, incumbent upon a grass or corn-field, whilst the air above is clear and bright with the rays of the sun; we may even walk along the foot-path across the field, with the lower part of our body enveloped in this mist, whilst the upper is perfectly free from its humidity.

This phenomenon of mist at sunrise, is consequent upon the calm of the over-night having admitted rapid radiation to ensue from the earth and its produce, which then became so much lower in temperature than the great volume of the atmosphere at a more lofty elevation, that the volume reposing upon the earth and its produce, was suddenly deprived of an extremely great amount of its aqueous vapour, and then the mist—or earth cloud—thus formed, acted like an aerial cloud, as already noticed, page 216, and screened or prevented any farther radiation from ensuing towards the clear sky, and therefore reposed until dawn.

Let us now remark another beautiful phenomenon in connexion with this present subject of inquiry; although at sunrise the dense white mist reposes upon the surface of grass and corn-fields, although innumerable dew-drops bespangle the trees, plants, herbs, and flowers, beneath its envelopment; as the sun mounts higher in the heavens to run his appointed course, mist and dew-drops vanish, the earth and its productions become dry. Because the water of the mist and of the dew-drops, gains sufficient heat to change from its visible vesicular and liquid state, to that of invisible attenuated vapour, which the partly desiccated atmosphere immediately receives and treasures in its own capacious volume throughout the ensuing glowing day; but at its close—if the sky be calm and cloudless—the earth and its productions again radiate the stores of heat which they

had absorbed from the noon-tide sun ; they again sustain diminution of temperature, the air again commences its wondrous work of relinquishing its aqueous treasure as mist and dew, in just proportion for the relief and sustenance of all.

Thus “dew after heat refresheth;” thus the earth by its peculiar habitudes, as regards the reception and radiation of solar heat, resists an excessive or destructive accumulation of the imponderable agent, and maintains a temperature conducive to the well-being of the animated Creation.

These are the pleasures and advantages yielded by the just pursuit of experimental Chemistry, whilst ardently examining, and if possible, humbly interpreting, the varied phenomena which preserve the order and harmony of the Creation ; they all unfold volumes of wonders, and manifest—as in the case we have just considered—the truth of the Scriptural aphorism that declareth—“Who seeketh wisdom early, shall have no great travail, for he shall find her sitting at his doors.”

It is only of late years, that man has been permitted to interpret and understand the direct physical cause of dew, but from the earliest ages he has experienced and acknowledged its wonderful and beneficial effects, more particularly in those countries where rain seldom or ever falls ; hence the Sacred Writings are so replete with eloquent passages and splendid metaphors concerning the blessings attendant upon the presence, and the miseries consequent upon the absence of dew ; the following have been selected.

“For the seed shall be prosperous ; the vine shall give her fruit, and the earth shall give her increase, and the heavens shall give their dew.”

“God give thee of the dew of heaven, the fatness of the earth, and plenty of corn and wine.”

“The heaven over you is stayed from dew, and the earth is stayed from her fruit.”

“I will make your heaven as iron, and your earth as brass.”

The last metaphor admitting of interpretation to the

effect, that the intense power of the sun should directly heat the entire volume of the atmosphere, and render it so arid or anhydrous, that neither dew nor rain should descend, that the earth should consequently become so parched and hardened, as to be incapable of being dug or ploughed into furrows for the reception of seed.

Knowledge concerning the phenomena and laws of the Creation is not directly revealed to man, he must attain it by the diligent exertion of his noblest faculties; and the subjects which he then classes together in the form of a science, are, when mentioned in Scripture, always couched in language accommodated to sensible appearances and popular notions, as in the foregoing and many other passages.

In Egypt, the wind, in traversing extensive tracts of heated sandy deserts, becomes so desiccated or anhydrous, as to be incapable of depositing dew; whilst that in crossing the Mediterranean is so saturated with aqueous vapour as to be capable of depositing dew in abundance.

In England, the deposition of dew from the atmosphere is generally less during the continuance of easterly than of westerly winds; a phenomenon attributable to the different nature of the surfaces over which these winds travel, the former in crossing the continent of Europe become comparatively anhydrous, the latter in sweeping over the Atlantic ocean become comparatively enhydrous, and require but little reduction of temperature for the copious deposition of dew to ensue upon terrestrial objects.

The form of a dew-drop presents a philosophic mind with a subject for investigation; why is it either a perfect sphere, or some modification thereof, and not cubical, octohedral, or of any other geometrical figure?—why does it equally adhere to the upper and under surfaces of the blades of grass?

Because the impress of perfection is set upon every work of the Creator, and He permits man to discover that a sphere is a perfect and simple figure, the constituent particles of which are disposed around one common centre

of attraction, and being thus equally and simultaneously attracted, no other figure can possibly result, unless some superior attractive force be externally presented.

A sphere is the figure assumed by liquid water when a portion of it is either unsupported, or supported by a solid surface for which it has only a small attraction, but it becomes more or less spheroidal in proportion to the greater or smaller extraneous attraction of the solid surface.

Thus the form of a drop of rain or of dew is spherical, whilst descending from the air; and it preserves such form when it is received at a minute solid point of contact at the upper surface of a dry blade of grass, and will even gently roll unto its pointed extremity and pass to the under surface, and there remain pendent; the attraction of the minute solid point of contact with the blade of grass being superior for a time to the attraction of gravitation.



Fig. 48.

If several small drops coalesce into one large drop, the point of solid contact likewise increases, and then becomes far superior to the inherent attractive force between the mobile liquid particles, and thus, drawing them away from each other, causes them to assume the form of a spheroid; but this will remain adherent to the upper surface of the blade, or even continue pendent from the lower for a time.

By the successive addition of smaller drops, the size of the spheroidal drop becomes so great that the surfaces can no longer oppose the attraction of gravitation, therefore, the drop gradually becomes more and more oblate, until at length it rolls or falls away, and instantly loses its form amidst the capillary pores of the earth; from whence it is again destined to ascend as vapour, to mingle with the air, again to condense and descend as rain or dew, or other forms suited alike to time and season, for not a solitary drop of

water that falls is lost or annihilated throughout the miraculous works of Omnipotence.

When drops of water fall heavily upon the generality of vegetable productions, the abrupt shock forces them into such extensive contact with these surfaces and with each other, that in place of remaining as beautifully defined spheres and spheroids, they rapidly coalesce into slender cylindrical streams of water, and thus flow away into the soil, with the exception of a few drops, which sometimes escape this collision, and yet remain clinging to the attractive terminal points of the leaves, or other points of contact.

The surfaces of many leaves are covered with an extremely fine powder which—like fine dust on the floor of a room—is repulsive of gently sprinkled water; thus brilliant globules repose upon the leaves of the cabbage and the garden poppy; when these are shaken by the wind, or by the hand, the globules glide about without wetting the powdered surfaces, and although they may divide into many more globules,—the most minute always having the most perfect spherical form—they instantly exert attraction for each other upon contact, and coalesce to form one or two large spheroidal forms of silvery radiance.

Chemistry proves the petals of many beautiful and delicate flowers to contain minute portions of aromatic essential oils, having little or no affinity for water, accordingly the surfaces imbued with these are rendered incapable of rapidly absorbing either drops of rain or dew by which their fragile structures might be injured.

A drop of pellucid water, thus reposing on the crimson petals of a rose, and sparkling like a diamond in the morning light, presents many more attractions to the scientific inquirer regarding its cause, than it displays as outward beauties to the casual admirer of its form.

In connexion with this examination regarding the cause of the spherical and spheroidal figures of water when unsupported, or supported upon surfaces for which the liquid has

little or no attraction ; it may be remarked that the feathers of birds, aquatic birds in particular, are imbued with an oily secretion which renders them eminently unattractive of water.

Thus the majestic swan, after diving its graceful neck beneath the liquid stream, withdraws it perfectly free from humidity, and proudly erects it in the air ; or, if the spray of a light



Fig. 49.

wave dash over the body plumage of the bird, the sparkling drops coalesce into one or two large and brilliant globules, which repose upon the snow-white feathers of its back, neither wetting nor disturbing their soft and regular arrangement.

Water-fowl swim about boldly, dive deeply, remain for a considerable time under water, then rise buoyantly with dry and unruffled plumage to its surface.

The foregoing, and many analogous phenomena, must present themselves to the most indifferent observer ; they are popularly called instances of the repulsion of water by pulverulent and oily substances, but the correct scientific expression is, that such substances have not so great an attraction for the drops of water, as their own inherent molecules have for each other, accordingly they preserve as much as possible the spherical form which they had when deprived of support.

The dew that we have been considering, consists of water very nearly pure, and therefore differs from a thick sweet liquid that is frequently observed to collect on the leaves of trees during autumn, and is popularly called "honey-dew."

This liquid is shed by a species of insect known in Entomology under the name of *aphis*, it dwells upon the lower side of the leaves, and when this honey-dew escapes from its body, it is received by the upper side of the leaves, beneath those upon which the insect dwells ; this liquid is

very deleterious to vegetation, as it fills the pores of the leaves and disturbs their proper functions of transpiration and absorption; they soon become diseased, and from originally reflecting a brilliant green, they reflect a dingy yellow colour. But this honey-dew is a favourite food with ants, and these insects may very frequently be observed crawling up exceedingly lofty trees, in order to gain a supply of it from the leaves.

Several contrivances for detecting the presence of watery vapour in the atmosphere have been mentioned, page 181, as hygrosopes, the principle of an instrument known in the laboratory as the hygrometer, for measuring the quantity of aqueous vapour present in the atmosphere, now demands our attention.

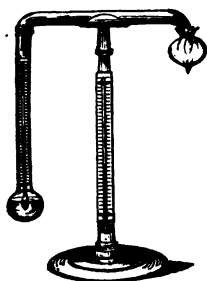


Fig. 50.

The instrument consists of a small and delicately constructed cryophorus containing ether instead of water; the two thin glass bulbs are about an inch and a quarter in diameter, and are connected by a glass tube, the horizontal part of which is about the eighth of an inch, and the perpendicular part about a quarter of an

inch internal diameter; the horizontal part is made of thicker glass, that it may be strong, and not liable to be crushed when inserted into the small spring-clip on the top of the brass standard, to which is attached a small and sensitive mercurial thermometer.

The horizontal part of the tube is generally four inches, and the perpendicular part six inches in length; this latter includes another and equally sensitive mercurial thermometer, but having an elongated or pear-shaped bulb—merely to facilitate its introduction into a tube so small—this dips fairly into the ether, with which the lower glass bulb is three quarters filled; the upper bulb is smoothly covered with a

piece of fine cambric secured around the tube by thread; a small capillary neck, closed by melting the glass, protrudes about a quarter of an inch beyond this covering; such is the appearance of the instrument, when adjusted for use, but its construction is as follows:—the perpendicular tube and its bulb are first made, and the small thermometer introduced, then the horizontal tube and its bulb with the capillary neck open are made; the left hand extremity of this tube is afterwards melted or welded to the end of the perpendicular tube; this being done, ether is introduced through the capillary neck, until the bulb unto which it belongs is very nearly filled; then, by inverting the instrument, the ether is caused to flow into the bulb attached to the tube containing the thermometer.

The flame of a spirit-lamp is gently applied to this bulb that the included ether may boil—this it will do at 96° ; or 116° below the boiling point of water—its vapour will expel the whole of the air from the interior of the instrument through the capillary neck, and when the ethereal vapour itself fully and fairly issue forth, the opening of the neck is suddenly closed, by melting it together in the flame of the lamp: thus the greater portion of the liquid ether remains imprisoned in a vacuum, as regards the absence of air, but is subject to the pressure of its own vapour, a condition analogous to that of the water in the cryophorus, page 178; the bulb is then enveloped in cambric; the standard with the thermometer is provided, and the instrument is completed.

Should any ether enter the covered bulb, this must be grasped in the hand, and by holding it as directed for the cryophorus, the heat of the hand will expand the ethereal vapour, and force the liquid ether into the other bulb; at the same time a sensation of cold will be experienced by the palm: for ether cannot change from a liquid to a vapour, or, technically evaporate, without a certain degree of heat; this it abstracts from the hand, which by such a loss feels cold.

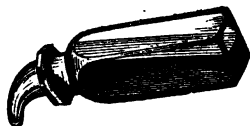


Fig. 51.

When the whole of the ether have entered its proper bulb, the instrument is to be placed on the sill of an open window—or still better upon a table in the open atmosphere—nearly level with the eye, taking care that a dark tree, wall, or other

object at some few feet distant, will throw it into strong relief.

The different thermometers will indicate the same temperature:—this must be noted—then from a small bottle, provided with a conical tube stopper having a minute orifice, a few drops of ether are to be let fall upon the cambric envelope.

Ether, having a smaller capacity for heat than water possesses, will immediately gain sufficient from the bulb for its conversion into vapour, or for its evaporation; the bulb will be reduced in temperature, the vapour of the ether that it contains will be condensed therein as liquid ether, as the vapour of the water was first condensed into liquid water when experimenting with the cryophorus, page 179; as in that case, so in this, a demand is immediately made upon the bulb containing the thermometer and the liquid ether, for a portion of vapour to supply the place of that which has been condensed, and there being no air within the instrument to oppose this demand, it is instantly supplied by the ether gaining heat from the bulb in which it is contained. This vapour in its turn is condensed; and as the ether still evaporates from the capillary attraction of the cambric, another, and another, and so many demands are made in rapid succession, that the bulb containing the ether, by yielding heat, becomes extremely cold—as its included thermometer will indicate—and at length so cold, that the aqueous vapour contained in the surrounding atmosphere wafting against it, is condensed as a fine ring of dew upon its exterior surface coincident with the level

of the remaining liquid ether; this ether does not become solid by the cold like the water in the cryophorus, because it is an uncongealable liquid, at the lowest known temperatures, and on this account it is chosen for introduction into the construction of the hygrometer.

The fine ring of dew is instantly detected by the strong relief into which the transparent bulb is thrown by the dark distant object—the bulb may be made of dark purple glass for the yet more ready detection of the dew-ring—the internal thermometer indicates the temperature at which the phenomenon occurs; this is noted, and called the dew-point.

Suppose the internal thermometer to indicate 48° , and the external thermometer to indicate 60° , the difference between the two is 12° ; it is therefore inferred that the atmosphere does not contain a very large amount of watery vapour, since a reduction of temperature so considerable is required for the deposition of the dew-ring. Suppose the internal thermometer to indicate 64° , and the external thermometer to indicate 66° , the difference between the two is only 2° ; and it is therefore inferred that the atmosphere does contain a very large amount of watery vapour, since it is so prone to deposit dew by a slight reduction of temperature; therefore in the first instance the degree of atmospheric dryness may be denoted by 12° , and in the second by 2° ; or the fact may be more concisely stated, namely, the more widely the thermometers differ in their indications, the smaller is the quantity of vapour in the atmosphere; and the more closely they agree in their indications, the greater is the quantity of vapour in the atmosphere.

Thus, in exceedingly dry weather, the cambric will require to be well saturated with ether several times before it can produce sufficient reduction of temperature to summon the scanty portion of watery vapour to chill and deposit as the dew-ring; whilst in extremely damp weather the addition of a very few drops of ether to the cambric will

produce sufficient reduction of temperature to summon quickly the large portion of watery vapour that is present in the air, and which it can barely retain, to chill and condense as dew upon the plain bulb.

Experimental proof of these facts may be gained by employing the hygrometer, first in a hot dry room, when great difference will be observed between the thermometers at the moment of the dew-point; and next in a cold damp cellar, when little difference will be found between them at the moment of the dew-point; indeed if the air of the cellar be already naturally saturated with vapour, or if the air of a small room be artificially saturated with vapour, by evaporation from a large wet cloth or blanket hung across a line near its ceiling, the two thermometers will closely coincide at the moment of the dew-point.

In England the degree of atmospheric dryness seldom amounts to 30° , but in the Deccan Shabarpore—an island situated near the mouth of the river Ganges—at a temperature of 90° , the dew-point has been seen as low as 29° , thus marking the aridness of that unwholesome atmosphere at 61° .

In deeply scientific investigations accurate experiments have been made with the hygrometer, and elaborate tables have been constructed to show the actual weight of aqueous vapour contained in a local volume of the atmosphere at the time that the dew-point is ascertained; these tables and calculations, although interesting and important to chemists and meteorologists, would scarcely be intelligible to general readers and juvenile students, therefore no reference will be made to them during this inquiry regarding the chemical phenomena of the Four Seasons.

From what has been stated concerning the construction and method of employing the hygrometer, the manner in which it may be caused to act as a weather-glass—in the popular acceptance of the term—to indicate the dryness and dampness of the atmosphere, and therefore the lesser

or greater probability of rain may be sufficiently intelligible.

Watery vapour, although invariably present in the whole atmosphere, and its mean quantity expressed by the enormous sum given at page 21, is liable to local variations of its weight, according to local variations of the temperature that it may sustain; for it has been ascertained, as at page 175—that warm air either calm, or in motion as a gentle breeze, or as a high wind, is capable of evaporating and invisibly holding in its volume more water than cold air, under similar conditions of repose and motion.

Refined experiments conducted by the chemist and meteorologist confirm the fact, that a cubic foot of absolutely anhydrous air—consisting of nitrogen, oxygen, and carbonic acid—when at the temperature of 33° , does not absorb or sustain more than two grains and one-third of a grain of watery vapour; whilst at the temperature of 60° it will absorb and sustain five grains and three quarters of a grain, and at the temperature of 70° it will absorb and sustain eight grains.

This experimental fact accounts for the greater rapidity with which a pool, or other accumulation of stagnant water is dried away—even by the naturally hydrated atmosphere—in warm weather than in cold weather, and it also accounts, in a great measure, for the more copious deposition of dew in the one season than in the other.

In some cases a parched volume of the atmosphere in motion as wind, travelling from one clime to another, over the wide expanse of sea or ocean, incites the rise, and accumulates so large a proportion of pure watery vapour upon its wings, as to be unable to sustain the whole burthen during its flight or transit, accordingly a portion is slowly and gently relinquished in the mysterious form of clouds of vesicular vapour.

These aqueous vesicles eventually coalesce, and descend as liquid rain drops upon the earth; but in other cases a parched volume, or nearly anhydrous blast, is ordained to

sweep over arid sands or deserts, and in place of refreshing these with a copious supply of water, it actually deprives them of their very scanty store of this inestimable compound for its own specific hydration, and thus often causes a most intense and almost insupportable sensation of heat.

These phenomena are most particularly evident in Eastern climates, and being familiar to the most ignorant observers, they were chosen by the Saviour of mankind as a medium for conveying a just and powerful reproof to the captious malevolence of benighted minds concerning the utter vanity of physical knowledge, if not combined with perception of the excellency of faith.

"When ye see a cloud rise out of the west, straightway ye say, There cometh a shower; and so it is."

"And when ye see the south wind blow, ye say, There will be heat; and it cometh to pass."

"Ye hypocrites, ye can discern the face of the sky and of the earth; but how is it that ye cannot discern this time?"

"Yea, and why even of yourselves judge ye not what is right?"

The physical cause of the phenomena to which these powerful allusions are made, may be thus interpreted:—the Mediterranean sea is situated immediately to the west of Judea, and, during the prevalence of a westerly wind, yields sufficient vapour to form a rain-cloud for the refreshment of the land; whilst the hot countries of Egypt, Ethiopia, and Arabia, situated immediately to the south of Judea, during the prevalence of a southerly wind, so greatly deprive it of moisture as to parch the land on which it ultimately arrives.

The hydration of the atmosphere is imperatively requisite for the welfare of the animal and vegetable creation; animals cannot breathe, and plants cannot grow in anhydrous air; it will immediately derange, suspend, and ultimately destroy their exquisite functions of vitality.

Chemistry reveals the fact that pure water is a direct

poison to aquatic beings, and that the water they inhabit requires mixture with air—or aëration—for their respiration, precisely the same as the air by which we are surrounded requires mixture with aqueous vapour—or hydration—for our respiration.

For the sake of illustration, imagine rain to fall into a hollow or basin at the summit of a lofty mountain, and to accumulate there as a lake; we ascend the mountain, and reach the lake, and then experience something more than mere bodily fatigue; we breathe with difficulty, perhaps with pain; and if we cast a net into the water, we find it either very scantily supplied with fishes, or entirely free from them.

How are we to account for the oppression that we feel, and the absence of the fishes from the water? As follows:—the air is not so abundant upon the mountain summit as it is in the valley; it is more rare, more attenuated, and therefore our lungs do not inhale the volume which they have been accustomed to receive either in the valley or upon the level earth; the water of the lake thus exposed to an atmosphere so rare cannot become sufficiently aërated to support the respiration of fishes.

Suppose even that aërated water were exposed at this great elevation from the ocean level, it would immediately part with its air, to supply the rarity of the surrounding atmosphere, with nearly the same rapidity as it would to supply a vacuum. The latter fact can be experimentally illustrated: place a large glass filled with clear river or spring-water, upon the plate of the air-pump, cover it with the large receiver, then proceed to exhaust it as described, page 166; myriads of small bubbles will emanate and ascend from all depths of the water; these consist of air originally and invisibly dissolved in the water, and which had no tendency to escape therefrom under the ordinary pressure of the atmosphere on the level from whence the water is taken; but as the air is exhausted from the receiver, it is freed from pressure, therefore the dissolved air expands;

rises, and ultimately escapes from the water to supply the vacuum.

In place of allowing all the bubbles to escape, remove the screw of the valve-chamber, that the external air may be admitted to the receiver, its pressure will immediately force back those which remain into solution again with the water, it will then appear as clear as it did originally.

If river-water be boiled for two or three hours, its dissolved air will be expelled by the heat of ebullition, 212° , and after allowing the water to cool down to atmospheric temperature in a tightly corked bottle, if it be poured from this slowly and without guggling into a finger-glass, and then a small fish introduced therein, the creature will immediately show signs of distress by raising its head above the surface, and gasping for breath, and would soon die if kept immersed; if it be removed, and the water poured from the height of two or three feet from the finger-glass into another, and so on alternately for a few minutes, then upon immersing the fish a second time, it will not show such signs of distress as it did at first.

On the one hand, the water contained no air, and accordingly the fish gasped at the surface to obtain a supply from the external atmosphere; on the other hand, by pouring the water for a time from one vessel to another, it became aerated, and the fish could breathe with more freedom.

Fishes breathe in consequence of their respiratory organs being fitted to withdraw oxygen; not from the water itself, but from the air that it is capable of dissolving, and of holding dissolved, under all ordinary circumstances.

Chemistry applies these facts to the explanation of a beautiful natural phenomenon: the unaerated azotic water of the lake overflows its bounds, and under the influence of gravitation falls as a cataract over the mountain side; each moment that it increases in velocity it passes into denser and denser regions of the atmosphere, and in the hurry and turbulence of its fall over rugged masses of rock, struggling against their impediments to its course, it is agitated amidst

the air, exerts attraction for it, dissolves it, foams with its bubbles, then flows down and onwards throughout the valley and plain, as a stream or river, sufficiently aerated for the support of aquatic beings, and in it they are then discovered to abound.

The description of this phenomenon may be aided by reference to the accompanying engraving, in which the horizontal shading being strong below, faint in the centre, and faintest above, may denote, as at page 170, that the atmosphere is dense at the level surface of the earth, light at a great altitude, and lightest at the greatest elevation, or the mountain summit; upon this the unaerated water of the lake is supposed to be, and as it overflows and falls through the successive strata of the atmosphere, as indicated by the increasing intensity of the shading, it dissolves more and more air, until, upon its arrival in the densest strata of air, as indicated by the strongest shading, it becomes highly impregnated and furiously turbulent with aerial foam.



Fig. 52.

Much of the grandeur of a mountain torrent is referrible to the tremendous velocity of its rugged fall, and the powerful shock with which the water and air incorporate, to produce the turbulent foam and the deafening roar.

The rapid fall of water through a vacuum to a solid surface produces no foam, there being no air for it to dissolve; but it produces a crash like that of the violent collision of two massive metallic surfaces, because there is no elastic medium to act as a spring, and break the velocity of its descent; this fact was exemplified on a minute scale, by shaking the water in the cryophorus, page 178, from one of its bulbs to the other.

As the mountain torrent traverses the sloping earth in returning to its parent ocean, it widens its course, exposes a larger surface to the atmosphere, becomes more powerfully aerated by the contact, the rippling and the waves into which it is thrown by breezes and winds.

If a vessel were filled with water thus powerfully aerated, a small fish then placed therein, and the mouth of the vessel afterwards accurately closed with an air-tight cover, the creature would die when its respiration had consumed the greater portion of the oxygen of the dissolved air; it would die, although immersed in water that actually contains oxygen as an element; but this oxygen—be it remembered—is combined with hydrogen, and the respiratory organs of the fish have not the power of separating it from such chemical combination as they have of separating it from its mechanical mixture with nitrogen, which constitutes the chief volume of atmospheric air.

Fishes demand a constant supply of fresh aerated water for their existence, the same as animals demand a constant supply of fresh hydrated air for their existence, for both classes of beings are soon destroyed by an accumulation of the mephitic products of their own respiration.

Agas might probably elapse before either of these extraordinary media, air and water, would become vitiated or

unfitted for the maintenance of life, on account of the incomprehensibly enormous volume and bulk in which they naturally abound; but Chemistry discovers that the Almighty has made the same beneficent provision for purifying water from the deleterious results of the respiration of aquatic beings, as He has made for purifying air from those of the respiration of man, and the higher order of animals.

All things are miraculously balanced and adjusted throughout the Creation; all things manifest the power and goodness of God; and above all branches of human science, that of Chemistry is singularly favoured in being permitted to become the medium of examining and interpreting so many wonders.

During the bright weather of summer and autumn, most plants—especially the *conferva rivularis*—growing in pools, ponds, and streams, are covered with myriads of small air globules,—this is an observation; the chemist devises means of collecting these globules in a receiver, and finds that a lighted taper introduced therein will burn with unusual brilliancy,—this is an experiment; he reasons upon this, and, guided by analogy, tries if the air from all plants of a similar character, when exposed to light, will present the same phenomenon; he discovers that they will do so, and thus establishes a scientific truth.

In the presence of light, aquatic plants have the power of decomposing the carbonic acid produced by the respiration of fishes, and of eliciting oxygen nearly pure, globules of which ascend and collect in the receiver, and will support the flame of a taper with greater brilliancy than the external atmosphere in which oxygen is mingled with nitrogen.

Two or three handfuls of the *conferva rivularis*, collected carefully, without injuring the fragile vegetable structure, may be introduced into a large globular water-bottle—a carafe—having a long narrow neck—the narrower the better—the bottle must then be perfectly filled with water from the pool, pond, or stream from whence the growing

plant was taken; place the palm of one hand over the mouth of the bottle to close it firmly, and, with the other, holding the globular part, invert it; pass the first hand beneath the surface of three or four pints of water contained in a basin—either glass or earthenware—then withdraw the palm of the hand from the mouth, no water will escape from it, because the weight of the water included in the bottle is inferior to that of the external atmosphere; thus the bottle will remain perfectly full of water with its globular part uppermost, and containing the filaments of the conferva.

On account of the weight being so much above the narrow support of the mouth, the bottle would be liable to fall from this upright position, it must therefore be carried in the basin to an open window, where the sun is shining with its greatest splendour, the basin set on one side of the window sill, and a heavy brick or flat stone placed against it to prevent it from slipping; the bottle is then to be moved from its upright position, still keeping its mouth under water, that its globular part may securely rest against the angle of the window frame as shown in the annexed engraving. This simple arrangement is precisely similar in

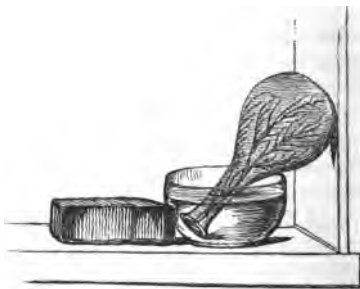


Fig. 53.

principle—though on a larger scale—to the well known globe fountain that is placed inside a breeding cage, or the conical fountain that is placed outside a small bird cage, with its horizontal neck passing inside; the globular water bottle will act similarly to these contrivances.

For example, the water in either form of fountain is prevented from running out by external atmospheric pressure, but as the birds sip away the water from the cistern of the one, or from the neck of the other, air will ascend into the globe or cone, and cause an equal bulk of water to fall; as this is sipped away, air will again ascend, and water will again descend, so at length each fountain will become exhausted of water, or rendered dry, and will only contain air.

The utility of either contrivance consists in the very small surface of water presented to the external air, and therefore it cannot dry away or evaporate with the rapidity that it can from a wide shallow glass, or even from the large orifice of a common bird-glass, but remains for days without requiring to be replenished.

These bird-fountains, simple as they may appear, and unworthy of attention as they may be deemed, involve the principle upon which all the refined and accurate apparatus is constructed by the chemist for extending his researches regarding the nature of gases and vapours, be they invisible as oxygen, or coloured as chlorine.

From contrivances and facts the most simple, have emanated the most important inventions and discoveries which adorn all branches of experimental science, but that of Chemistry more particularly, does not necessarily involve the possession of costly or complicated apparatus, its aim is simplicity, and by endeavouring to keep this steadily during our inquiry, we have been hitherto, and shall be henceforth enabled to conduct many curious and instructive experiments by the employment of vessels and materials in ordinary use.

The display of large, accurate, and costly apparatus on the well arranged table of a professor of Chemistry, is, generally speaking, indispensable, because in a public lecture-room he has to demonstrate the facts of the science to assembled hundreds; experiments therefore require to be performed on a scale of magnitude, and with the greatest promptitude and precision, so that they may be simultaneously witnessed by the whole audience, the lecture-room being the arena for general, not for individual instruction.

Much, sometimes the whole of such apparatus may be discarded from the quiet chemical laboratory, and simple means employed for the elucidation of important facts; thus the grand discovery of oxygen—seventy-nine years ago—was made by the employment of a globular glass or flask, about the size of a globe fountain, with its mouth inverted into a cistern; but instead of containing water, both vessels contained liquid mercury, and in that of the globular glass was placed a portion of red precipitate—page 89, its composition being unknown—from which, when heated by the rays of the sun in August, drawn to a focus in a powerful lens, the element now recognized as oxygen was educed, and collected as the air may be collected in a bird fountain.

But in the present arrangement of the globular bottle, basin, water and conferva, the artificial concentration of the solar rays is not required, their natural splendour alone is necessary, and after it has beamed upon the plant for an hour, its slender filaments will become studded with innumerable globules of oxygen, which will gradually increase in size, and spontaneously quit the attraction of the filaments—or will do so if the apparatus be slightly shaken—and ascend to its upper part, where, by the addition of more globules, which will continue to rise, all will coalesce into one large bubble after a few hours; a portion of water of corresponding bulk, having descended into the basin, this water being expelled by the oxygen evolved within, exactly

as with the bird fountain, it is expelled by the air ascending from without.

Allow the arrangement to remain exposed to the sunshine throughout the whole summer or autumn day, in order to obtain as much oxygen as possible, then kindle the end of a long and slender splinter of wood, pass one hand beneath the water in the basin, and with the palm close the mouth of the bottle, then with the other lift it, and remove it to stand in its usual position upon a table; the bubble of oxygen will thus ascend into the neck; slide away the hand from its mouth, and quickly introduce the end of the splinter, it will burn with far greater brilliancy than it did previously in the external air; nay, probably if the flame be withdrawn and extinguished, so as to leave merely a glowing cinder, this upon introduction to the oxygen will burst into flame.

The rationale of the whole proceedings may be stated thus:—the water contained carbonic acid, the aquatic plant, excited by solar light, decomposed the mephitic, secreted its carbon, and elicited oxygen, which collected in the glass, and no diluent nitrogen being therein present—as in the atmosphere—or in other terms, no impediment to the intense affinity of such oxygen for the carbon and hydrogen of the splinter, its flame augmented in brilliancy and rapidity of combustion, as in a former experiment, page 93.

Experiment justifies the conclusion that fresh-water plants and marine plants derive the chief, if not the entire, weight of their constituent carbon from carbonic acid, either absorbed directly by the waters from the atmosphere, or produced from the air they contain by the respiration of fishes; thus aquatic vegetation removes excess of carbonic acid from the waters, the same as terrestrial vegetation removes excess of carbonic acid from the atmosphere.

The vesicles of the sea-weed, botanically named *fucus vesiculosus*, or commonly bladder-wrack, when recently collected, contain air more highly oxygenated than the atmosphere, and after removing the *conferva* from the bottle, if

it be filled with water and inverted as before, and many of the vesicles punctured with a pin, and gently pressed, whilst immersed in the water just under the mouth of the bottle, air will ascend from them, which, by management as directed, will be found to support the flame of a splinter with more brilliancy than the external atmosphere.

The foregoing appear to be the miraculous phenomena ordained by the wisdom and beneficence of Almighty for decomposing the mephitic results of the respiration of fishes, by the vital functions of aquatic plants when stimulated by the ethereal agency of light, and thus we have revealed another beautiful instance of the mutual dependence of the two organic kingdoms; fishes produce and exhale carbonic acid; water-plants decompose such compound, and increase their own structures by combination with its carbon, whilst they emit its oxygen, which dissolves in the water, or ascends into the air, and mingles with its due proportion of nitrogen.

This mixture is again absorbed by water, respiration is again supported, carbonic acid is again produced; it is again decomposed, and from being azotic, is rendered a pabulum of life; incessantly do these wonderful phenomena proceed, incessantly do they afford proofs of the power and beneficence of the Almighty in providing for the welfare of all His creatures.

Fishes invariably become languid and sickly when kept in glass globes filled with river water; they were taken from a pond or stream of water naturally aerated, and fitted for their life to continue by the vital action of growing plants, but being suddenly transferred into a confined portion of the same water, in proportion as they consume the oxygen of its aëration, they contaminate it with the carbonic acid of their own respiration, and there being no growing plants in the glass globes to effect its decomposition, the creatures inevitably suffer from its accumulation, and ultimately die, if fresh water be not supplied.

For the life of fishes to continue in these artificial receptacles, it becomes necessary to change the water very frequently, and also to introduce therein some aquatic plant—the *Vallisneria spiralis* for example—not only to decompose the result of their respiration, but to afford them shelter from the intensity of the sunshine, for, like animals, they occasionally require protection against its light and heat.

A silver-fish had long been the brilliant and spotless inhabitant of the clear water of a pond, surrounded by lofty trees, casting shadows in which it could occasionally derive shelter from the direct rays of the sun ; these trees were cut down, and the water exposed to the full glow of light ; shortly afterwards the fish appeared with a brown spot upon its back, like a scorch ; this increased in colour and size, and according to the examination of a naturalist and a physiologist, it was certainly a sun-burn, produced as follows:—solar radiant heat will pass through air, water, or any other perfectly transparent substances, without imparting heat to them, page 55 ; when the rays impinge upon opaque solid bodies, heat is instantly arrested and absorbed by them ; thus the back of the silver fish was scorched by its opaque solid organic tissue, absorbing heat that had passed through the transparent liquid water without elevating its temperature.

An experiment can be performed in direct proof of this curious fact; obtain a very large gold-fish globe, wipe its exterior and interior perfectly clean, fill it with the most pellucid water that can be procured, place it to stand in the bright sunshine, then, with the largest glass lens or burning-glass that can be obtained, collect the rays of the sun to a focus, direct this through the surface of the water in the globe ; the transparent burning-glass will not become hot, neither will the transparent water into which its focus falls, as may be proved by plunging the hand into the water near, but not actually in the focus.

If the hand be moved into the focus, it will immediately

feel a scorching sensation, because its opaque solid surface absorbs the heat, and if a very powerful lens be used for the experiment, a piece of wood placed in its focus under the water will be charred, or other opaque solid bodies capable of absorbing heat, will be so heated that the water in immediate contact with them will become warmed; convective currents, page 55, will be established, and thus indirectly, the temperature of the whole bulk of water above the focus will be raised; but not the portion beneath it, as water is a non-conductor of heat, a fact that will engage much of our attention when considering the leading chemical phenomena of the season of winter.

Another equally remarkable experiment may be tried in proof that the solar rays do not heat the transparent media by which they are transmitted; remove the *conferva* or other plant from the large globular bottle or carafe that was employed in a former experiment, page 239, cleanse its interior and exterior thoroughly, fill it to the brim with the most pellucid water that can be obtained—if the water have been previously boiled to expel the air, and then allowed to cool down to the temperature of the air, so much the better—then tie a piece of well-moistened bladder closely over its mouth, taking care to exclude every bubble of air; lastly, holding the neck, turn the globular part upwards, it will appear like a ball of solid glass although it is full of liquid water.

Place a piece of amadou tinder upon the window sill or other support, according to the situation selected for the experiment, in the bright sunshine; hold the bottle that the solar rays may impinge upon it, move it about at various distances from the tinder, and evidence will be soon gained that the rays are concentrated, when the focus falls upon and kindles the tinder, but the bottle and the water will remain cold.

Hence the danger of leaving globular bottles and gold-fish globes full of water near window curtains, papers, or boxes

of matches during a brilliant sunshine ; the position of the glasses might accidentally be such as to collect the rays of the sun and to direct their foci upon the inflammable materials, indeed this actually happened to a box of matches placed near a globular show-bottle of transparent liquid in a shop window upon which the sun shone brilliantly.

Attention may next be directed to some other phenomena equally wonderful, and in many cases doubtless equally important, although the exact purpose which they are destined to fulfil, may not as yet be clearly determined.

During summer and autumn may be frequently observed large air-bubbles spontaneously collecting and bursting upon the surface of stagnant water, and if the mud beneath be disturbed with long pole or rake, many thousand of such bubbles will quickly appear on the surface of the water.

Chemistry has devised means for collecting this exhalation, and upon analysis it is discovered to be neither atmospheric air, oxygen, nitrogen, nor carbonic acid, but a gas consisting of carbon 6+hydrogen 3, combustible and burning with a yellow flame ; it is identical with the fire-damp of coal-mines, and contains the same elements, though not in the same proportions, as the gas obtained from coal for the purpose of artificial illumination, and to denote that it consists of carbon and hydrogen it is named carburetted hydrogen, or sometimes to denote its source, it is named inflammable gas of ponds and marshes.

This inflammable gas may be collected without difficulty by a contrivance similar in principle to that of the bird-fountain, page 241 ; for example :—select a very large glass tumbler having a stem and foot, place one end of a slender, but not elastic pole, about ten or twelve feet long, against the stem of the tumbler and fasten it thereto with string, so that upon holding the pole horizontally, the mouth of the tumbler will be downwards ; provide also a small earthenware or glass desert-plate, and carry this arrangement to the brink of the pond.

Stretch over the water the end of the pole to which the tumbler is fastened, and gradually sink it therein that it may become filled, then carefully turn the pole in the hands that the foot of the tumbler may be uppermost, cautiously raise it that the mouth of the tumbler may only be about an inch beneath the surface of the water, the tumbler will then remain full, for a reason given page 240 ; thus hold it steadily, whilst an assistant with a pole or rake stirs the mud at the bottom of the pond, immediately beneath the mouth of the tumbler ; many of the bubbles of gas thus disturbed will ascend and displace the water from the tumbler until they fully occupy its space ; then, still keeping its mouth under water, gently draw the pole towards the person that the tumbler may be brought within arms' length, when an assistant, stooping towards it, can place the small plate in the water beneath the mouth of the tumbler, and thus aid in lifting it out of the pond ; then the string must be cut away, leaving the tumbler supported mouth downwards on the plate, and the gas that it contains prevented from escaping by the small quantity of water held in the plate.

Carry this arrangement within doors, place it upon a table, darken the apartment, kindle a match, hold this in one hand, take the foot of the tumbler in the other, and steadily raise it, keeping the mouth downwards, about a foot from the plate, then bring the lighted match to the mouth, the gas contained in the tumbler will instantly kindle and produce a yellow coloured flame.

The mouth of the tumbler is directed to be held downwards because carburetted hydrogen gas is of less specific gravity than air, and therefore cannot fall through air ; if the mouth were held upwards, the light gas would instantly rise through the air, and air would fall into, and fill the tumbler, so that the experiment would be unsuccessful, and it is by a correct knowledge of the specific gravities of air, gases, and vapours, that the chemist is enabled to collect, confine, measure, weigh, and transfer them from one vessel to another with

the greatest facility: some general account of the principles of the operation for weighing gases, will be presented at a future season.

The method now described for collecting carburetted hydrogen succeeds extremely well if the pond be in the immediate neighbourhood of the residence of the operator; if it be distant, no matter how many miles, a large wide mouthed glass stoppered bottle, the ground part of the neck and stopper being lightly touched with pomatum, may be substituted for the tumbler and fastened at the end of the pole with its open mouth downwards; then, proceeding as directed, the bottle may be filled with gas, the ground stopper inserted under water, the bottle lifted and unfastened from the pole; the stopper tied down with string, thus the gas will be effectually confined and may be carried to the residence, and its inflammable property demonstrated upon the removal of the stopper in an inverted position, and applying the lighted match.

Carburetted hydrogen, is presumed to be formed at the bottom of stagnant ponds and also in the water of marshes by the spontaneous decomposition or decay of vegetable productions; and when it is kindled either by lightning or some unknown agent, it is probably the cause of the light that so frequently appears during summer and autumn evenings flickering and dancing over the surface of marshy and boggy soils, presenting the phenomenon of the *ignis fatuus*, popularly known as Jack-o'-the-lantern, or Will-o'-the-wisp.

In this country the beautiful spontaneous light of the glow-worm, and of the hundred-legged worm—when the latter is irritated—are both well known; but in hotter climates this luminous appearance is exhibited in a more remarkable degree by the lantern-fly and the fire-fly: nothing certain has been discovered regarding the cause of the phenomenon; it is probably referrible to the slow combustion of the element phosphorus, which these insects

have the power of secreting ; it may be exactly imitated by gently rubbing the phosphoric paste of a lucifer match in the dark.

The decayed or touch-wood of old forest trees may be often observed to emit a pale light spontaneously ; also some kinds of fungi, if struck, as by the foot in walking over them at night ; some flowers, as the tuberose, nasturtium, and marigold, occasionally present brilliant flashes of light towards the close of warm evenings.

The remarkable luminosity of the ocean occasionally depends upon the presence of decomposing organic matters, but more frequently upon numbers of minute aquatic beings which have the power of emitting light, sometimes of silvery whiteness, at others of amethystine purple and emerald green.

In all the foregoing instances, the emission of light is called the phenomenon of phosphorescence, and the bodies which present it are called phosphorescent substances ; several animal matters are thus phosphorescent when deprived of vitality, and long before their putrefaction commences ; and of these the flesh of the carp, tench, herring, sole, crab, and lobster are the most remarkable ; this luminosity is seldom presented by the dead flesh of quadrupeds, and never by that of birds under any circumstances of putrefaction.

Chemistry discovers water to be an active agent in sustaining the life of animals and vegetables, and after its cessation, in promoting their decay, more especially when the element nitrogen is present in their organized structures.

Upon the cessation of vital power, in organic matter, the elements escape from their normal union, and exert new affinities for each other to produce compounds which are generally gaseous or vaporous, and always deleterious to animal life ; a fact that demonstrates the absolute necessity of burying the dead bodies of animals and vegetables deep beneath the surface of the earth, that it may absorb the

noxious products of their putrefaction, and ultimately convert them into nutriment for the support of fresh vegetation; or, in other terms, the putrefaction and decomposition of organized bodies in the free atmosphere are mephitic processes, whilst beneath the earth they are salutary operations.

"In this case, the food of plants is prepared where it can be used; and that which would offend the senses and injure the health if exposed, is converted by gradual processes into forms of beauty and of usefulness; the fetid gas is rendered a constituent of the aroma of the flower, and what might be poison, becomes nourishment to man and animals."

It has long been familiar to physicians, that there is produced by wet lands, or by marshes and swamps, a poisonous and æriform substance, the cause not only of ordinary fevers, but of intermittents; and to this subtile agent of disease, the term marsh-miasma has been applied: nor is such knowledge confined to physic; throughout the world it is a fact known to the vulgar, and even to the less enlightened nations.

It is familiar to the rural inhabitants of Lincolnshire and Essex, who refer to the fens of these districts the source of the agues under which they so commonly suffer; it is known to the rural inhabitants of certain districts of France, Holland, and Italy—in this last country more particularly as malaria—it is also known to the uncivilized negroes of Africa.

"The fairest portions of Italy are a prey to this invisible enemy malaria; the fragrant breezes are poison, the dews of its summer evenings are death; the banks of its refreshing streams, its rich and flowery meadows, the borders of its glassy lakes, the luxuriant plains of its overflowing agriculture, the valleys where its shrubs regale the eye and perfume the air, are the appointed regions of this malaria."

"Death here walks hand in hand with the resources of

life, sparing none ; the labourer reaps his harvest but to die, or he wanders amid the luxuriance of vegetation, a sufferer from his cradle to his grave ; aged even in childhood, and laying down in misery that life which was but one disease ; he is even driven from some of the richest portions of this fertile, yet unhappy country ; and the traveller contemplates at a distance deserts, but deserts of vegetable wealth, which man dare not approach, or he dies."

In England this malaria, called marsh-miasma, is the cause of ordinary and intermittent fevers, and often exerts its baneful power upon the husbandman at the very season when his bodily strength and activity are most demanded for the pursuit of his agricultural labours ; and knowing this from sad experience, he sedulously endeavours to ward off the insidious exhalation, or altogether to arrest its sway, by cutting down exuberant vegetation, draining the marshes of stagnant waters, and removing the corrupting deposit of organic mud : these efforts are frequently successful in restoring the salubrity of limited districts ; but some are so extensive, and so rife with the subtle agent of disease, as to defy amelioration by the utmost exertion of human foresight or labour, and they accordingly remain proverbially insalubrious.

In crowded cities and towns, where the streets are narrow, the buildings badly drained, imperfectly ventilated, and scantily supplied with water for cleansing away putrefying organic offal ; or, if through wilful indolence and neglect, it be suffered to accumulate and ferment in the heat of summer or autumn, it will inevitably produce and evolve infectious and contagious matters, which will occasionally display their deadly powers in all the horrors of plague and pestilence.

The Almighty has not permitted the chemist to discover the elementary or compound nature of these mephitic exhalations ; for a volume of the stagnant atmosphere of a pest-house, crowded with human beings suffering under the

most malignant disorders, will present upon its analysis the same constitution as a volume of the fresh breeze of an open valley, whose inhabitants are enjoying the inestimable blessing of health.

But the Almighty has mercifully permitted the chemist to discover agents, and to employ them for the destruction of malarie; these are known as nitric acid and chlorine.

The composition of nitric acid has been mentioned, pages 15, 17; it may be produced by passing a rapid and long succession of electrical sparks through a confined volume of atmospheric air, the elements of which are thus incited to exert chemical affinity; but for all practical purposes, the acid is educed by the distillation of sulphuric acid with nitrate of potassa, the latter being a native product of the earth, and popularly called nitre; the process is extremely simple, as single equivalents of the respective agents alone are required, and admits of the following explanation:—

Nitrate of potassa = 102, consisting of nitric acid 54 + potassa 48; sulphuric acid = 40, consisting of sulphur = 16 + oxygen 24; water = 9, consisting of oxygen 8 + hydrogen 1; the nitrate of potassa is decomposed, potassa 48, combines with sulphuric acid 40, and produces sulphate of potassa = 88, nitric acid 54 is educed, but instantly combines with water 9, and constitutes hydrated or enhydrous nitric acid = 63, in which state it is commonly known, but it can be de-hydrated, or rendered anhydrous, and then appears as solid crystalline nitric acid = 54.

Place a tea-spoonful of powdered nitre in a dry flask, then pour upon the substance about the same quantity of sulphuric acid, which in its ordinary liquid state is hydrated; warm the bulb of the flask very gently over the flame of a spirit lamp, the changes just described will ensue, and the vapour of the hydrated nitric acid will escape from the mouth of the flask—avoid its inhalation for it is highly irritating and poisonous—when thus educed from a much larger quantity of nitrate of potassa, and permitted to

mingle throughout an infected atmosphere, it will destroy all the subtle deleterious matters that may be therein contained, but chlorine is better adapted for such purpose, and for its evolution and management, full directions will be given in the sequel.

Nitric acid is a colourless, or very pale straw coloured liquid, which exhales fumes of the hydrated acid vapour when poured from one vessel to another, its powerful action upon organic and inorganic bodies may be demonstrated by the following experiments :—

Cut three or four of the interior leaves of a red cabbage into small shreds with a clean knife, place these in a clean earthenware jug, and pour into it about a pint of boiling water, cover the mouth of the jug with a clean folded napkin, and thus allow the vegetable matter to macerate until quite cold.

Unfold the napkin, spread it over a clean basin, pour the whole macerated contents of the jug thereon, gather the four corners together, then squeeze the napkin; there will ooze from it into the basin a clear infusion of a beautiful blue colour, pour this into a clean wine-bottle for use, throw away the solid residue as useless.

Let three or four drops of nitric acid fall into a tall ale-glass, then fill it with the infusion, its blue colour will change to red, and as it will do so with every acid that is commonly known, it is constantly employed as a test of the presence of acids; paper when stained with it is also conveniently used for the like purpose.

Thrust a white kid glove into an ale-glass, then pour upon it about half a fluid ounce of nitric acid, stir the two together with a flat strip of box or lance-wood, the acid will immediately act on the animal matter of the leather and the vegetable matter of the wood, and cause the former to shrivel, curl, and ultimately form a soft semi-fluid mass, and change the pale yellow colour of the latter to an intensely dark brown.

Procure a book of copper leaf—it is commonly sold for decorative purposes—place three or four of the leaves in a tall ale-glass, and pour upon them twenty or thirty drops of nitric acid, intense chemical affinity will instantly ensue; a deep orange coloured vapour will arise and flow over the brim of the glass, the brilliant solid metal will vanish, and a dark green coloured liquid will remain.

The equivalent number of nitric acid is 54, and that of copper 32, but 4 of nitric acid = 216, and 3 of copper = 96, are concerned in producing the foregoing phenomena, which may be thus explained: nitric acid = 54 is decomposed, and reduced to nitric oxide gas = 30, by copper = 96 combining with its oxygen = 24 to produce oxide of copper = 120; the nitric oxide gas = 30, ascends in the glass, and meets the air, from which it takes oxygen = 16, and produces nitrous acid vapour = 46, and it having a greater specific gravity than the air, flows over the brim of the glass; nitric acid = 162 remains undecomposed, and exerts affinity for oxide of copper = 120, combines and produces nitrate of oxide of copper = 282, which dissolves in the water that is present, and forms the dark green coloured liquid; so that the experiment, although occupying only a few seconds, involves a series of very remarkable chemical changes, the explanation of which will be materially aided by reference to page 15, where a tabular view is presented of the compounds of oxygen and nitrogen.

It may be here remarked that no metal can combine with an acid, a metal must be previously combined with oxygen, or oxidated, and then such oxide will combine with an acid; this important fact being understood, the foregoing compound of nitric acid and oxide of copper, is conventionally called nitrate of copper; but nitre is not called nitrate of potassium, because the oxide of that metal is named potassa, and with it the nitric acid combines, so that the compound is called nitrate of potassa.

Chlorine is educed from common salt, not by direct, but

by indirect action as follows: salt consists of chlorine and sodium, sulphuric acid contains water, and it consists of hydrogen and oxygen; place a quarter of an ounce of salt in a saucer, pour upon it twenty or thirty drops of sulphuric acid, a dense white fume will be evolved which is extremely irritating to the lungs, if accidentally inhaled, and precisely similar in composition to that employed for the destruction of the geranium or myrtle in a former experiment, page 151, in fact when it is dissolved in water, the solution constitutes the commercial hydrochloric acid employed in the experiments, page 181, upon the decomposition of carbonate of lime.

During the above apparently simple proceeding, a refined chemical change ensues, the sodium of the salt unites with the oxygen of the water to form oxide of sodium or soda, this unites with the actual sulphuric acid to form sulphate of soda, whilst the chlorine that was united with the sodium, combines with the hydrogen that was united with the oxygen, and thus the two elements, chlorine and hydrogen, produce chlorhydric or hydrochloric acid.

Single equivalents of all the substances are concerned in the foregoing experiment, and they sustain the following remarkable changes; sodium 24, combines with oxygen 8, to produce oxide of sodium 32, this combines with sulphuric acid 40, and produces sulphate of soda 72; whilst chlorine 36, combines with hydrogen 1, and produces chlorhydric or hydrochloric acid 37, it is therefore a true product and not a true educt, it is formed, not liberated, during the experiment. From such chlorhydric or hydrochloric acid thus produced from materials in which it was not present, if the hydrogen be removed, the chlorine can be educed, which was present in one of them, namely, the common salt; the experiment can be satisfactorily performed by attention to the following directions:—

The two substances which are commonly known by the names of litharge and red-lead, are distinct oxides of lead,

the one consists of oxygen 8 + lead 104, and the other of oxygen 24 + lead 208, the first, or the protoxide, can combine with acids, the second, or deutoxide, cannot combine with acids.

Mingle half an ounce of red lead, with a quarter of an ounce of common salt, place the mixture in a tall narrow glass; pour a tea-spoonful of water into a small earthenware cup, then pour slowly into this an equal portion of sulphuric acid, by such mixture the liquids will become warm on account of the specific gravity or density of the water being increased, and its capacity for heat being thereby diminished, page 163; let it cool; then pour it upon the mixture contained in the tall glass, and at the same time stir the materials about with a strip of wood.

During this proceeding, in addition to the formation of sulphate of soda, as in the first experiment, will be the formation of a portion of sulphate of lead, simultaneously with the formation of hydrochloric acid, but this is instantly dehydrogenated by a part of the oxygen of the deutoxide of lead, water is produced, and chlorine educed in the state of a greenish-yellow coloured vapour which will arise and fill the tall glass; care must be taken to avoid inhaling the vapour, for it, like nitric acid, is a deadly poison, and yet, like that substance, it is a destroyer of poison, thus by causing its evolution in an infected atmosphere, the subtil virus will be effectually destroyed.

The exact rationale of the foregoing changes which terminate in the education of elementary chlorine from compound hydrochloric acid, although rather complicated on account of the number of equivalents of the acting substances which are essentially concerned, may be readily understood from the ensuing description.

Chloride of sodium 2 equivalents = 120, consisting of chlorine 72 + sodium 48; sulphuric acid 6 equivalents = 240, consisting of sulphur 96 + oxygen 144; 6 equivalents of water = 54, consisting of oxygen 48 + hydrogen 6; and

2 equivalents of deutoxide of lead = 464, consisting of oxygen 48 + lead 416.

During the mutual reaction of these materials the following changes ensue: chloride of sodium 120 is decomposed, water 18 is decomposed, sodium 48 combines with oxygen 16, and produces oxide of sodium or soda 64; chlorine 72 combines with hydrogen 2, and produces hydrochloric acid 74; sulphuric acid 80 combines with the soda 64, and produces sulphate of soda 144, this dissolves in the remaining undecomposed water 36; deutoxide of lead 464 is decomposed, and reduced into the state of protoxide of lead 448, this combines with sulphuric acid 160, and produces insoluble sulphate of lead 608; whilst oxygen 16, elicited during the transition of deutoxide of lead 464, into protoxide of lead 448, combines with hydrogen 2 contained in the hydrochloric acid 74, and produces water 18, and this action simultaneously educes chlorine 72.

All the foregoing changes afford admirable illustrations of the definite weights in which elements and compounds combine and separate in reference to the weight of hydrogen as a standard of unity, page 29; a correct knowledge of these facts is of the utmost importance to the chemist, and also to the manufacturer of chemical agents, as it enables them both so to adjust the weights of substances that they may either combine or separate without excess or loss.

The yellow colour of the vapour of chlorine, its density and action upon organic and inorganic bodies, may be illustrated by the following experiments: they should be performed in the open air, in order that any portion of the deleterious element happening accidentally to escape may be instantly wafted away from the operator.

Select a quart wide-mouthed flint-glass bottle, put therein double the quantity of common salt, red-lead, and diluted sulphuric acid employed in the first experiment, page 257; an evolution of chlorine will immediately ensue, it will expel the air from the bottle, and supply

its place with yellow vapour—this is now technically called the atmosphere of the bottle—the colour will be more evident upon looking into the bottle from a height of three or four feet, or by placing it to stand in the centre of a large sheet of white paper.

Pour a tea-cupful of the blue infusion of cabbage into a half-pint wide-mouthed flint-glass bottle, then take the quart bottle containing the chlorine, bring its mouth close beside that of the other, then raise it with the same action of the hand as if about to pour out a liquid; a portion of the heavy chlorine vapour will actually pour out with nearly the same readiness as a liquid, will descend into and fill the half-pint bottle, there display its colour, and—if the bottle be slightly shaken—its power upon the blue vegetable infusion by discharging or bleaching the colour.

If a piece of tainted meat be next placed in the bottle with the bleached liquid, its mouth closed with a cork, and left for half an hour, upon pouring all the contents out together into a large pailful of water, and washing the meat, the offensive odour that arose from its taint or putrefaction will no longer be emitted.

Place two or three leaves of Dutch yellow metal—which consists of an alloy of copper and zinc—in a clean dry half-pint wide-mouthed flint-glass bottle; and pour chlorine into this from the quart bottle, the metallic leaves will instantly kindle and burn with the emission of a vivid red light, on account of the intense affinity of chlorine for the constituent metals of the alloy, with which it produces the compounds called chloride of copper and chloride of zinc.

For the effectual fumigation of large apartments or buildings by chlorine, the extraordinary and invaluable element may be most advantageously evolved from a mixture of four pounds of common salt, one pound of bin-oxide of manganese, —oxygen $8 \times 2 = 16$ + manganese 28, it is cheaper than red-lead, but similar in its principle of

action—two pounds of sulphuric acid, and two pounds of water; no precautions are required for mixing the two former, but great precautions are required for mixing the two latter.

The water must be placed in a large earthenware pan, then the sulphuric acid must be poured in as a very slender stream, promoting the mixture of the liquids by stirring round and round with a wooden paddle, and ultimately allowing the whole to become cool: if sulphuric acid be plentifully and suddenly added to water, the heat evolved is so great that it will generally break a glass, and sometimes an earthenware vessel.

The heat is evolved because the water, being the lightest liquid of the two, when it energetically combines with the sulphuric acid has its density increased, and its capacity for heat decreased, and this in a far more remarkable manner than in the experiment with the alcohol and water, page 163; thus dangerous accidents have happened to persons either ignorant of this fact or careless of its consequences.

The mixture of common salt and bin-oxide of manganese must be weighed into five portions of one pound each, and placed in as many quart or three-pint shallow brown earthenware pans—used for holding flower-pots—thus charged they are to be placed in succession upon the five uppermost treads of a high pair of steps set in the centre of the apartment that is to be fumigated, the windows being closed, and if it contain a chimney, a sack of hay or shavings must be thrust therein to stop its draught effectually.

A common table, on which is placed the earthenware pan containing the diluted acid, and a half-pint jug, is then set alongside the pair of steps, the operator mounts the table, then dips the jug into the diluted acid until about three parts full, and immediately pours this upon the mixture in the uppermost pan on the steps, then a like quantity upon the mixture in the second, and so on until all be charged.

Care must be taken throughout the whole operation to avoid placing the face either level with, or below the pans, lest chlorine should be accidentally inhaled, and those only who have experienced its dire effects upon the respiratory organs can form any notion of the excruciating torture that it produces—it can be alleviated by placing in the mouth a lump of sugar soaked in brandy and a few drops of sal volatile, but every care should be taken to avoid its inhalation, even when extensively diffused throughout the atmosphere—all the acid being added to the mixture in the pans, the operator then leaves the apartment, shutting and locking the door. The apartment is left undisturbed generally for two days, then the windows are to be opened from the outside, that a current of fresh air may enter and sweep through to expel any remaining chlorine, and after the lapse of an hour the door may be opened; the operator can then safely enter and remove the pans; their contents may be thrown into the nearest drain, and will destroy its effluvia; they can then be arranged and charged again, and the apartment closed for the same time as at first, then unclosed with the same precautions, the pans removed, and their contents thrown away.

The apartment may then be considered to have undergone a thorough fumigation, for no infectious or contagious matter can escape the destroying agency of chlorine.

The pans containing the mixture of common salt, binoxide of manganese and diluted acid, are directed to be placed at a considerable elevation, because chlorine is more than twice the weight of air—s. g. 2.470—and therefore will descend and uniformly mingle throughout its volume, which is the grand object of the whole proceeding; if the pans were placed on the floor, the heavy chlorine would chiefly repose thereon as a distinct stratum, and not rapidly or uniformly diffuse itself throughout the entire atmosphere of the apartment, therefore the fumigation would be imperfect.

The substance popularly known as chloride of lime, is

made by exposing anhydrous or slaked lime to the action of chlorine, and is more correctly denoted as chlorinated lime; it contains, when properly made, nearly half its weight of chlorine, not united with any strong degree of affinity, and therefore readily escaping when exposed to the atmosphere; on this account it is invaluable for the destruction of infectious and contagious matters, and the offensive odours which are emitted by the putrefaction of organic bodies.

The burning of incense or pastils, sprinkling "eau de Cologne," lavender-water, or vinegar in an apartment, will only cover an unpleasant odour, and will not destroy the virulent matter of which it consists: so burning feathers on a heated shovel, or stirring a basinful of vinegar with a red-hot poker, although fumes arise, and both operations are popularly esteemed "fumigations;" they are worthless as disinfectants; the mephitic matter remains in full potency, disguised, but not destroyed.

Chemistry reveals the extraordinary fact in illustration of the power by which elements and compounds are controlled, that chlorine, in its pure uncombined state, is a deadly poison, and a destroyer of deadly poison, whilst in its combined state with the metal sodium, it forms exactly sixty per cent. of the common salt which is an absolute requisite of life, and a most powerful antiseptic of dead organic matters.

Artificial heat of 220° will also destroy the subtle virus of contagion and infection; a fact well known to our forefathers, who during the awful times of plague and pestilence, kindled huge piles of wood, or large tar-barrels in the streets of infected cities and towns: such fierce combustions demanded an enormous volume of air for their support, and as it rushed forward loaded with disease to feed the flames, it became decomposed, and the intensely heated products of combustion swiftly ascended into higher regions, creating a strong draught throughout the streets, and com

pelling the voluminous entrance of purer air from the suburbs.

When the equilibrium of the atmosphere is disturbed by an extensive combustion, the draught produced is of extraordinary vehemence, amounting to that of a natural hurricane, as was fearfully exemplified during the conflagration of Moscow.

In time of plague, our forefathers resorted to the vicinity of iron-furnaces, metal-foundries, and works emitting sulphurous and other acid vapours; these, conjoined with the high temperature consequent upon their production or evolution, destroyed the aerial mephitic, for infection in such situations was but rarely taken; the vapour of burning sulphur—sulphurous acid—is still used in the East against the plague, but its power is feeble in comparison with that of nitric acid or chlorine.

Chemistry can neither isolate the above mephitic principles, nor the aroma of flowers from the atmosphere, although it must contain abundance of the latter at certain seasons; thus the flowering of beans often fills the air with fragrance absolutely palling to the olfactory nerves, and the air retains such vegetable perfume with great and persistent power, so that it is occasionally wafted by winds to extraordinary distances; thus the fragrance of the cinnamon, which is abundant in Ceylon, and that of the rosemary on the coast of Spain, have been smelt by persons at sea, even when many miles distant from those shores.

Flowers deteriorate the air to some extent, particularly during the night; it is highly probable, however, that much of the oppression frequently experienced by persons after remaining in a conservatory or a room profusely decorated with flowers, is more referrible to their concentrated aroma, than to their deterioration of the air.

The atmosphere is in perpetual motion on account of the convective currents which are established throughout its

vast volume by the universal agency of heat; thus breezes and winds are produced, and they tend to the effectual dispersion of the mephitic results of respiration, combustion, and putrefaction in such highly attenuated states, amidst the air, as to be rendered harmless, and beyond detection.

During the four seasons atmospheric motion displays its force in every degree; for example:—the gentle zephyr floating the thistle-down, and undulating the corn; the fresh breeze rippling the surface of the stream, and swelling the canvass of the bark; the tempest blast heaving the ocean into waves, and appalling the mariner; lastly, the fierce hurricane uprooting the oak of the forest, prostrating the harvest of the plain, and overwhelming the works of man with ruin and desolation.

The science of Chemistry leads to the conclusion that the word *nitre*, as it occurs in Scripture, does not denote the substance now popularly known by such name, or technically nitrate of potassa, for the properties of this substance do not resemble those of the substance to which allusion is made in the following passages:—

“Though thou wash thee with nitre, and take thee much sope.”

“As vinegar upon nitre, so is he that singeth songs to a heavy heart.”

Nitre or nitrate of potassa, is unfit for employment as a detergent in washing, neither will it form a soap, and vinegar poured upon it produces no remarkable effect; but another crystalline product of the earth in oriental climates, closely resembling it in appearance, is to be understood by the word *nitre* when used in Scripture, namely, a natural compound of carbonic acid and soda—a carbonate of soda—carbonic acid, $22 \times 3 = 66$ + soda, $32 \times 2 = 64$, anciently known as *natron*, which dissolves in a small quantity of water, and such solution is used for washing in many parts of Asia, and when heated with lime, and the clear solution

afterwards added to olive-oil, forms soap; the crystalline substance, from these two circumstances, is known in Egypt and various parts of Asia as soap-earth.

Upon this soap-earth—carbonate of soda—if vinegar be poured, the two substances are found incompatible, a foam or effervescence of carbonic acid being immediately expelled; and as vinegar—acetic acid—was well known in the earliest ages, the fact of its curious and sudden action upon natron, or the fact of the opposition between the two substances was taken as the foundation of a beautiful metaphor for illustrating the extreme incompatibility between songs and a heavy heart.

Probably the term nitre was occasionally applied to both native nitrate of potassa and native carbonate of soda, from the circumstance of their simultaneous occurrence in the soil of eastern countries, and their mutual resemblance to a great extent in appearance when extracted in a crude state from the earth.

Sulphuric acid frequently occurs native, particularly in the lakes and water-falls of volcanic districts, where it has been probably produced by the subterranean combustion of sulphur; but for practical purposes it is artificially formed in chemical works by burning sulphur, mingled with nitrate of potassa in the air of a chamber having a stratum of water upon its floor, and thus by the intervention of the oxygen contained in the nitrate of potassa, the fumes that would otherwise be only those of sulphurous acid, pages 38, 152, are incited to combine with an additional weight of oxygen from the atmosphere, and to become those of sulphuric acid, which immediately dissolve in the water that is present.

Common salt—chloride of sodium—the great source of the element chlorine, is obtained from the water of the ocean, or from that of brine-springs, by exposure of either in extensive shallow pits to the evaporating action of the warm atmosphere, or in pans to the vaporizing agency of artificial heat applied beneath them, as in the ordinary

process of boiling ; in either case, when the whole of the water is expelled in the state of volatile vapour, the fixed solid salt remains.

Both processes are conducted upon a gigantic scale for supplying salt, which is an essential addition to the food of man and animals ; it is therefore by the beneficence of the Creator most lavishly presented, not only in the ocean and brine springs, and thus requiring an amount of chemical knowledge for its extraction therefrom, but as a solid crystalline deposit of vast extent in the strata of the earth, and wanting only mechanical labour for its "getting."

This variety of chloride of sodium is called rock-salt, to denote its native hard solid state ; whilst the two varieties just named are called sea-salt and bay-salt ; the meaning of the former term is obvious, that of the latter has reference to the vessel technically called a bay, in which brine is pent up and subjected to the action of heat, or that it was formerly caused to form a salt-bay, over a certain tract of land, for spontaneous evaporation to ensue and deposit salt.

Rock-salt is quarried like stone, in large crystalline cubical masses, frequently pure, colourless, and transparent as ice, sometimes variously coloured by native metallic compounds and unknown principles, or contaminated to a considerable extent by sulphate of lime—gypsum—page 40 ; this last variety of rock-salt, upon exposure to the atmosphere, will soon lose its actual saline matter, or chloride of sodium, by the solvent power of watery vapour and rain, whilst the sulphate of lime will resist such solvent agents to a remarkable extent, and will therefore remain solid and devoid of taste.

A natural analysis or separation of the common salt from the gypsum is thus ultimately effected, similar to the artificial analysis or separation of the salt from the sand in an experiment formerly made, page 68 ; and knowledge of this fact enables the chemist to venture upon an interpretation of a passage in the New Testament, in which passage,

as in many others, allusion is made to familiar things, in order to convey important truths.

"If the salt hath lost its saltness, wherewith shall ye salt."

"It is fit for nothing but to be cast out, and trodden under foot."

In such case the salt from its universal employment as a condiment to food being the valuable, and the gypsum from its inutility for such purpose being the comparatively worthless portion of the compound mineral product.

Again, in the Old Testament, occurs the following passage:—

"Can that which is unsavoury be eaten without salt? or is there any taste in the white of an egg?"

This passage evidently proves that the use of salt, as taken with food to confer flavour upon it, was known in the earliest ages; but the reason of its utility in entering from food into the constitution of the blood, and other fluids of the animal body, and a correct knowledge of its own chemical composition, are facts that have only been determined within the last half century.

Having thus generally examined the important points connected with contagious and infectious effluviæ, and their destruction by the chemical agencies of nitric acid, chlorine, and heat, attention may be next directed to other phenomena of autumn.

By the recondite power of vitality, vegetables select elements from the atmosphere, the waters, and the earth, secrete and elaborate them, to increase their growth and the formation of the proximate principles fit to minister to the sustenance of man and animals: prodigious indeed is the amount of these refined operations, and of the store of nourishment they produce as a grand and important feature of autumn.

"Lift up your eyes and look on the fields, for they are white already to harvest."

The corn-harvest is the most important of all the varied treasures of autumn, therefore a few general observations upon the chemical nature of the proximate principles contained in wheat, and to which the nutritive property of good bread may be referred, will be found interesting and useful at this stage of our investigation.

In the corn harvest the utmost care is taken that the sheaves are perfectly dried, and cleansed from weeds before they are carted from the fields and housed in barns or stacked in rick-yards, that there may be no danger of heating from the effects of damp, and that the store may remain sound and fit for conversion into wholesome food.

Methods of thrashing, winnowing, and grinding grains of wheat into flour, were devised in the remotest ages, and are frequently mentioned in the Sacred Writings; many improvements upon these original rude methods have been made, but all are so well known as to require no particular notice in this inquiry: if we turn our attention to the wheaten flour, its examination will present some information that is not so generally familiar. For example, knead a pound of fine wheaten-flour with water into the shape of a ball, hold it beneath a slender stream of water, continue to knead it between the hands, and receive the water that runs from the ball of paste or dough into a clean pail; this water will be milk-white; when it fills the pail, set the vessel aside; continue to let water run upon the paste or dough, and from it to waste, until it flow off perfectly clear, and then will be left strongly adherent to the hands, a considerable portion of a grey coloured, tough, elastic substance: this is gluten, one of the proximate principles of the wheaten flour, educed therefrom by the action of the running water.

Gluten when submitted to ultimate analysis, yields the four ultimate elements, carbon, hydrogen, oxygen and nitrogen, as at page 44; and, on account of containing the last element in considerable abundance, and so approximating the composition of the fibrin and albumen of the animal

body, gluten is frequently called a vegeto-animal principle, for it gives to the articles of diet in which it exists, a nutritive power nearly equal to that of animal food; the flour of wheat contains more gluten than that of any other grain: hence the superiority of wheaten bread over barley bread, rye bread, and oaten bread; it is lighter and more digestible.

Chemistry discovers that the warmth of the season materially affects the formation of gluten in wheat; that it is most abundant in the wheat of southern climates, and hence this is peculiarly excellent for the manufacture of vermicelli and macaroni which are very nutritious articles of diet.

If gluten be perfectly dried by long exposure to a heat of 212° it becomes hard, brittle, and will undergo no change by keeping, whereas if it be moist it will rapidly enter into putrefaction and exhale the same horrible odour as that emitted by putrefying flesh, and for the same reason, because it contains nitrogen, and this, combining with hydrogen, forms the volatile substance ammonia, page 33, whilst other compounds equally deleterious are formed by the new arrangements into which the elements are thrown during the progress of putrefaction. Upon examination of the milk-white water in the pail, it will not be found so white as it was when it ran from the ball of dough, and by gently inclining the pail on one side that the water may slowly pour away, a white sediment or precipitate will remain; this is starch, another proximate principle of the wheaten flour educed therefrom by the action of running water.

Starch, when submitted to ultimate analysis, yields the three ultimate elements, carbon, hydrogen, and oxygen, page 44, and no trace of nitrogen; starch, when moist, soon becomes acescent from the production of vinegar—acetic acid—but dried at 212° , it becomes solid and brittle, and may be kept for years without sustaining any decomposive change—as exemplified by seeds—it is insoluble in cold water, only mixes with it mechanically, and precipitates therefrom by repose; it is soluble in boiling water, and then produces a solution

more or less viscid according to the larger or smaller proportion of starch that is present; this solution, when cold, added to an aqueous solution of the element iodine, will produce a deep blue colour, which is esteemed by the chemist as a specific characteristic of starch, and enables him to recognize its presence during an analysis.

An aqueous solution of iodine is made by putting four or five grains of the solid element into a pint glass stoppered bottle filled with rain-water, and shaking it occasionally for a few hours; if a portion of this solution, which has a pale brown colour, be poured into one small vial containing a teaspoonful of wheaten flour, and into another containing a teaspoonful of grains of wheat, upon shaking the vials, the flour in the one will become blue, but the grains in the other will not change colour. Yet the grains of wheat must contain starch, or else the flour which they yield could not affect the iodine; why then does this element fail in detecting the presence of starch in the grains of wheat?

For a reason often presented in Chemistry during experiments upon organic and inorganic matter, namely, that mechanical structure or attraction of aggregation, opposes chemical attraction or chemical affinity, and in the case now before us, it is the aggregation of the thin yet hard coating of the husk around the grains which shields their starch from the affinity of the iodine.

Pour the mixture of the solution of iodine and the grains of wheat into a clean earthenware mortar, crush them with its earthenware pestle, and thus mechanically destroy their attraction of aggregation,—that of the iodine is already destroyed by chemical solution—and then the starch they contain will meet the iodine, and produce the blue colour as the flour did; this blue compound is called iodide of starch.

Again, if perfectly dry starch and perfectly dry iodine be rubbed together in a perfectly dry mortar, with a perfectly dry pestle, no blue colour will appear, because mere mechanical division of the two substances is insufficient to

cause them to exert chemical affinity, but the addition of a few drops of water will effect the chemical division or solution of the one, namely, the iodine, and, in this state, coming into contact with the insoluble starch—as in the case of the crushed grains—will combine with it, and display the blue colour of the resulting iodide.

Bread, of course, contains gluten and starch, the latter may be readily detected by placing a thin slice of bread upon a plate, and then moistening it with solution of iodine; from being white, or nearly so, it will become dark blue, the starch, although solid in the bread, is neither dry nor protected as it was in the grain; throw the stained slice of bread into boiling water, the blue colour will instantly vanish, because the iodide of starch is soluble in water at 212° .

Bread is insoluble in cold water, and therefore confers no taste upon it, but toasted bread thrown into cold water, and allowed to remain for some time—to form the well-known beverage toast-and-water—confers upon it a mucilaginous taste, because the heat of the fire has converted a portion of the original starch into gum, which is readily soluble in cold water.

At the same time, during the toasting of the bread, a portion of its original gluten, starch, and the newly-formed gum, are decomposed into volatile or empyreumatic substances, which cause the smoking and peculiar smell of the toast, after the first dampness or steam of the bread has passed away; but a portion of the carbon does not volatilize; it remains, forming the charred or burnt toast, and this thrown into the water colours it brown, and confers a peculiar well known flavour.

If bread be more perfectly toasted, so as to become very much charred, the resulting charcoal is not useless as might be supposed, for if it be shaken with water having an unpleasant odour or taste from long keeping, the charcoal will effectually purify it from both, and render it palatable; the

theory of this fact is not understood, but its practical application is fully appreciated at sea.

Starch, heated or torrefied in an oven until it acquire a brown colour, is converted into a substance resembling gum, being soluble in cold water, and incapable of affording a blue colour with solution of iodine; such artificial gum is largely employed in the arts, especially in the art of calico printing.

An aqueous solution of starch, kept at a boiling heat for several hours, produces gum; this curious change ensues more rapidly and perfectly if a portion of sulphuric acid be added to the original solution; then, after a second exposure to a boiling heat for several hours, the gum changes into grape sugar, which may be obtained in a granular form, by neutralizing the sulphuric acid with carbonate of lime, filtering and evaporating the filtered solution.

Chemistry discovers that all seeds and buds, roots, as those of the hyacinth, and tubers, as those of the potato, consist principally of starch, page 44; but close analysis reveals the fact of the contemporaneous presence of a minute portion of gluten, or other analogous nitrogenized principle, which during germination either induces or aids the starch to become soluble in the water of the soil, and to transmute into gum and sugar, which are also soluble.

No satisfactory evidence can be adduced regarding the physical cause of the circulation of the sap in plants, nor even of the general direction of its course, but the most accurate researches which have been made upon this abstruse subject render it probable that the chief ascent of the sap from the roots to the leaves, is in the vascular system of the *alburnum* and outer layer of wood, and that having performed its functions in the leaves, it chiefly descends by the *liber* or inner layer of bark, giving rise to the formation of new wood, and to the elaboration of gum, resin, and other proximate principles.

Gluten and starch are the chief proximate principles of wheaten flour, and may be readily educed therefrom by the simple action of cold water, which induces their separation, although it has no attraction for the one or the other, but the flour also contains minute portions of sugar and albumen, pages 44, 46, and phosphate of lime and phosphate of magnesia, page 41; these absolutely essential constituents require a very considerable amount of chemical skill for their eduction, and the necessary details would be unintelligible to the general reader, they are accordingly omitted; but it must be stated as a most remarkable and important fact, that the inorganic phosphates existent in wheaten flour or in any other substance used as food, are transferred from thence into the constitution of the muscles and bones of man and of the higher order of animals.

The utility of manuring wheat lands with recently crushed bones, consists in the fact, that the organic or tough matter of the bones, called albumen, page 46, in the presence of moisture, is extremely prone to enter into putrefaction, and thus to render soluble the phosphates of lime and magnesia with which it is associated; these inorganic compounds are then capable of being absorbed by the rootlets of the growing grain, and are chiefly transferred to the ear, which alone is fit for human food, whilst the silica and potassa of the soil, simultaneously absorbed by the rootlets, are wholly transferred to the straw, which is only fit for littering cattle. When bones are calcined or burnt, all their really organic matters, such as albumen, fat, and oil, are decomposed or dissipated, and nothing but their inorganic phosphates remain as bone ash.

This is not directly applicable as a manure, because it is insoluble, and cannot be received by the capillary rootlets of plants, and to render it of value to their growth, it requires artificial solution, or more correctly decomposition, to a certain extent by the action of sulphuric acid, which converts the insoluble phosphate into soluble phosphate.

Another most important office of the organic matter of fresh bone, and of all animal and vegetable manure containing nitrogen, is to supply such element to the growing crops; hence it is found that wheat grown upon soils chiefly manured with nitrogenous matters, contains a relatively large proportion of gluten. Growing vegetables have the recondite power of decomposing the ammonia, which is emitted into the atmosphere by the putrefaction of dead vegetable and animal matter, and thus they indirectly obtain an amount of nitrogen, for they have not the power of directly obtaining it from its mixture with oxygen, which constitutes the chief volume of the atmosphere; indeed, the element nitrogen may be considered to enter their vital structures indirectly from the decomposition of dead organic matter in the soil, and when the season of maturity is attained, such vegetables become the food of animals, the nitrogen then enters into the composition of their flesh, and this, when rendered fit for human food, yields its carbon, oxygen, hydrogen, and nitrogen, for the growth of the human body.

Quicklime is valuable as an application to soils, on account of its great causticity or corrosive power, reducing organic manures to a soluble form, fit for absorption by the roots of plants, and having performed this office, it gradually attracts carbonic acid from the soil and the atmosphere, and becomes carbonate of lime or chalk, in which state it absorbs the water of the shower or the aqueous vapour of the air, and thus preserves a store of nutriment for the plants that it supports. The offal of the fold-yard and the stable is invaluable as manure, because it returns to the soil a very large proportion of the proximate and ultimate elements which were taken from it by the growth of the hay and corn crops, it returns them in a state fitted for affording nutriment to the next vegetation with which the land may be planted, and which will neither flourish nor arrive at maturity, if heed be not taken re-

garding the proximate and ultimate elements of its constitution.

The proximate principle, gum, is contained in the generality of vegetable productions; it contributes to their nutritive powers, and when pure is soluble in cold and hot water, forming a mucilage; it frequently exudes spontaneously from the stems and barks of trees, as from the plum, cherry, apricot, and almond; but the substance most popularly known as gum, is the produce of the plant called the *acacia vera* of Morocco; the ultimate elements of gum are carbon, oxygen, and hydrogen, page 44.

The sweet taste of fruits depends upon the presence of sugar, a proximate principle, possessed of considerable nutritive power; it is soluble in cold and in hot water, forming a syrup which will yield four and six-sided prismatic crystals, as exemplified in sugar-candy, and thus materially differs in its physical state from gluten, starch, and gum, which do not assume crystalline form, or are amorphous; the ultimate elements of sugar are carbon, oxygen, and hydrogen, page 44.

The commercial supply of sugar is well-known to be the plant *arundo saccharifera*, called the sugar-cane, the annual consumption of which, and the vast amount of carbon it contains, have been already shown, page 123; but sugar has also been obtained in large quantities from the *acer saccharinum*, or sugar-maple, and the *beta vulgaris*, or beet-root, and it may be extracted from many vegetables and roots that have a sweet taste; but it does not uniformly assume the crystalline shape; thus, for example, grape-sugar is not crystalline, neither is honey-sugar; accordingly such varieties of saccharine matter are called granular sugars, and they contain more oxygen and hydrogen than crystalline sugars.

The elementary carbon contained in sugar may be educed in its black and solid form, by a very simple yet beautiful experiment: take half an ounce, by measure, of

the strongest syrup of white sugar; pour it into a very thin, narrow, and tall ale glass, set in the middle of an earthenware plate, then pour upon the syrup half an ounce by measure of the strongest sulphuric acid; stir the two liquids with a strip of wood, about a foot long; the mixture will darken, a powerful degree of heat will be evolved, a white vapour or steam will exhale, and a black mass of carbon will ascend in the glass.

The experiment may be thus explained: sugar consists of carbon, oxygen, and hydrogen; the two latter being in the weights requisite for the formation of water; this sugar, dissolved in a small quantity of water, constitutes syrup. Sulphuric acid has an affinity for water, but none for carbon, and when mixed with the syrup, it first combines energetically with its water, but then, not satiated, proceeds to combine with that of the actual sugar, and thus its elementary carbon is educed in a black and solid form.

Sugar must be present in all cases of vinous fermentation, a well known process which appears to depend upon the escape of a portion of the carbon and oxygen of the sugar in the form of carbonic acid, whilst the remainder, and the whole of the original hydrogen combine to form alcohol, consisting of carbon $6 \times 4 = 24$ + hydrogen $1 \times 6 = 6$ + oxygen $8 \times 2 = 16$.

In the case of vegetable matters, not inherently containing sufficient sugar, its formation is induced in them artificially by partial germination; thus, barley is converted into malt, or, in other words, its original starch is transmuted into sugar, as that of the cotyledons of a seed is changed during germination. The process of malting consists in moistening barley with water, heaping it together, and thus inducing germination to a certain extent, at which it will produce a maximum of sugar; vegetation is then checked or destroyed by the heat of a kiln, and the barley is said to be malted. It has an exceedingly sweet taste, and is ready to undergo vinous fermentation.

The saccharine juice of the grape is technically called "must," and as it runs from the wine-press, will spontaneously ferment, because it contains a peculiar form of gluten, that induces the change between the elements of the sugar, which are essential to the production of alcohol; but an infusion of malt, technically called "sweet-wort," does not contain this peculiar form of gluten, and accordingly requires the addition of a ferment containing nitrogen in the form of yeast, and then the production of alcohol will ensue.

It is a well known fact that fermentation never ensues in the grape itself, which if left upon the vine or gathered therefrom, shrinks and dries into raisins without producing the slightest trace of alcohol, and the cause appears to be, that the husk or membrane of the grape is peculiarly formed to allow of the transpiration of the water of its juice from the pulp, but to arrest the entrance of air or oxygen from without.

Grapes have been pressed in a vacuum, and the resulting must showed no tendency to ferment, when kept in the vacuum, but instantly fermented upon the admission of air; hence a bunch of grapes will become dry raisins if left unpressed, but will ferment and yield alcohol when they are crushed, and the air admitted to the gluten they contain.

The froth or scum that is well known to arise and collect upon the surface of liquors in a state of fermentation, consists of carbonic acid vapour; hence the danger of entering a room or cellar in which the process is conducted, because if there be not a strong draught of air from without, the confined atmosphere will become contaminated with the mephitic vapour, which is as eminently fatal to animal life as if it were more directly produced by burning charcoal in a brazier closely shut up in a room.

If a few lighted shavings be thrown into the carbonic acid arising from the fermenting liquor, their flames will be instantly extinguished, page 137; this curious fact was originally observed by a celebrated philosopher, and he was

thereby induced to undertake its more particular examination which led him to an able investigation of all kinds of aëriform matters, and the actual foundation of pneumatic chemistry, these labours were ultimately crowned by the important discovery of oxygen.

Carbonic acid is once and a half heavier than an equal volume of air at the same temperature, page 23, and considerably heavier than this if it be much colder than the air; thus suppose the process of fermentation to be conducted in a room, the floor of which is two or three feet below the level of the door-step, the carbonic acid as evolved from the fermenting tun would pour over its rim, and descend to the floor upon which—if there be no draught—it will quietly and invisibly settle up to the level of the door step, over which its excess will then pour away into the external atmosphere. Thus a person entering the room might stand near the fermenting vat, if not above his head, without experiencing any inconvenience, as he would be breathing air, but should he stoop, he would instantly become giddy and faint, by inhaling the mephitic lower stratum of carbonic acid vapour, and falling on the floor, become totally covered with it, his death by suffocation would immediately ensue.

Many fatal accidents have occurred through inattention to these facts, more particularly in breweries, where, after the liquor has been run from the vats, men attempt to descend for the purpose of cleansing them, and suddenly die, by encountering the invisible yet deadly vapour that still remains.

The precaution of letting down a lighted candle should never be omitted; if its flame burn as usual, the atmosphere within the receptacle is safe, if it become dim, there is hazard, if it extinguish, there is certain death awaiting the first person who descends.

The chief bulk of vegetables consists of the proximate principle called lignin or woody-fibre, and the diversity of forms in which they present it is extremely remarkable.

In a dense compact state, lignin constitutes the chief mass of forest timber; this is usually felled in autumn, and allowed to dry or season; it is then suitable for employment in the construction of dwellings, its extreme permanence fitting it admirably for such purpose; whilst its perfect insolubility in water, and its great buoyancy upon that liquid, render it of inestimable value for the building of ships.

"They that sail on the sea tell the danger thereof, and when we hear it with our ears, we marvel thereat."

"Nevertheless Thou wouldest not that the works of Thy wisdom should be idle, and therefore do men commit their lives to a small piece of wood, and passing the rough sea in a weak vessel are saved."

"Showing that Thou canst save from all danger, yea, even though a man went to sea without art."

"But Thy Providence, O Father, governeth it, and Thou hast made a way in the sea, and a safe path in the waves."

Thus are we enabled to visit and to explore the wonders of far distant climes, and to gain additional proofs of the wisdom and beneficence of the Creator, which are alike displayed at the equator and at the poles.

Miraculous indeed is the chemical fact, that the entire quantity of the solid element of timber, was once a constituent of the atmosphere, and has been withdrawn from thence and elaborated by the vital functions of the plant into union with the elements of aqueous vapour, to constitute the stately tree of the forest, the creeping ivy around its stem, the lowly moss at its foot, the tender verdure of the glade, the sweet flower of the dell, and every exquisite form of vegetation by which the surface of the earth is beautified and enriched.

But returning more immediately to the subject now under examination, it must be observed that all kinds of forest timber are not equally adapted for flotation; many are of greater specific gravity than water, and sink therein; this is the case with *lignum vitæ* and ebony; many are of lesser

specific gravity than water, and float thereon; this is the case with oak and pine; the actual proximate principle, called lignin, is of the same inherent or specific density in all these woods, but is closely compacted in those which sink, and loosely aggregated in those which float, and consequently involves amongst its pores a considerable volume of air, and this is the sole cause of the buoyancy of wood on water.

If the air be removed from a block of oak, it will no longer float on water, it will sink like a block of ebony: this fact may be experimentally proved.

Place a block of oak equal to about five or six cubic inches, in a saucepan filled with water, set the vessel on the fire, that the water may boil day after day, taking care to add more water from time to time to supply the loss of that which evaporates, the heated water will ultimately expel the air from the pores of the wood, and assume its place, and the inherent or specific gravity of the lignin will be demonstrated by the block of oak no longer floating upon the water, but sinking to the bottom of the vessel in which it is contained.

Select a piece of pine, about one inch square and five inches long; fasten to one of its ends a lump of lead, or coil it around with lead wire, page 94, sufficiently heavy to cause it to sink in water; then place the wood with the leaden weight downwards in a hyacinth glass; fill this to the brim with cold water, place it to stand upon the plate of the air-pump, and cover it with the receiver, page 166, having previously applied a touch of pomade to the ground surfaces, as there directed.

Proceed to work the handle of the pump, and as the exhaustion of the receiver ensues, myriads of air globules will emerge from all parts of the wood, ascend and break upon the surface of the water; proceed with the exhaustion until this appearance cease; then admit air; this will press upon the surface of the water, and force it to saturate the pores from whence the air escaped, as will be rendered

evident by the gradual subsidence of the water from the level of the brim of the cup of the hyacinth glass; lift the receiver from the pump plate, draw the piece of wood from the water, remove the leaden weight, replace the wood in the water, and it will immediately sink.

The loss of buoyancy sustained by wood, consequent upon the expulsion of air from the pores amidst its lignin, and their saturation with water, was strikingly exemplified in the polar seas; upon one occasion, during the agonies and struggles of a harpooned whale, the boat became entangled with the harpoon-line, and was drawn by the gigantic creature to such an extreme depth of the ocean, that the pressure of the water forced the air from the pores of the wooden planks, and assumed its place, so that the boat, when ultimately recovered by the whalers, was no longer capable of floating, and was worthless even for fuel.

In varying forms of compactness and strength, lignin constitutes the principal part of inferior plants, such, for example, as hemp and flax; these admit of being wrought by handicraft and machinery, into cordage, canvass, and linen, and when such fabrics are no longer applicable to their original uses, they can be converted into paper.

Lignin constitutes the delicate cellular arrangement or reticulated skeleton of fruits; it thus contributes to their form, and affords reception for their pulp and juice, and its elements, carbon, hydrogen, and oxygen, page 44, then slowly, yet certainly, relinquish their normal affinities, and assume those required for the production of saccharine and other matters, during the progress of ripening under the influence of light and heat.

Chemistry points out that lignin may be obtained pure from vegetables—from wood most readily—by removing all soluble extraneous matters with water, acids, or other agents, and that it is perfectly white, insoluble in water, the most permanent of all vegetable proximate principles, and solely consists of the three elements just named; so

that its combustion in the air produces only carbonic acid and watery vapour.

As lignin exists in the form of wood, it is associated with portions of earthy, saline, and alkaline matters which the tree, during vitality, secreted and elaborated from the soil in which it flourished; and accordingly, when wood is kindled, its actual or pure lignin produces carbonic acid and aqueous vapour, whilst the earthy, saline, and alkaline matters, being incombustible, remain as white ashes, which under ordinary circumstances are very light, and easily scattered by the wind: the expression in Holy Writ, "He scattereth the hoar-frost like ashes," has reference to the whiteness and lightness of the ashes of wood, as it was the chief fuel employed in the early ages of the world.

The ashes of wood and of other vegetables, when submitted to accurate chemical analysis, are found to contain a very large per centage of a compound called carbonate of potassa, derived from the potassa or oxide of potassium existing in the soil; indeed the great demand for potassa, commercially called potash, is exclusively met by the combustion of forest trees in those countries where they are so abundant as to be otherwise useless.

The chemist, knowing that lime has a strong affinity for carbonic acid, adds lime to carbonate of potassa, and thus forms insoluble carbonate of lime or chalk; whilst the potassa is liberated and remains in solution; this evaporated to expel the water, leaves solid potassa, or oxide of potassium.

This potassa, heated intensely with iron, yields its oxygen to such metal, and produces a rust or oxide of iron, whilst the potassium is emancipated in its elementary or metallic form, having the extraordinary property of floating upon and of decomposing water, page 138, and hereafter to be more particularly examined.

The uses of carbonate of potassa and of potassa are extremely numerous and important; both are consumed to

an enormous extent in the arts of dyeing, bleaching, and the making of glass; for oxide of potassium, or potassa, has the power of uniting with oxide of silicium or silica, page 85, and with many other metallic oxides to produce glass, either pellucid as natural crystal, or of colours as vivid and as varied as those which excite our admiration in the natural amethyst, topaz, ruby, sapphire, and emerald.

By the employment of pellucid glass, compounded of the oxides of potassium, silicium, and lead, fashioned into lenses of enormous magnifying power, man has been enabled to construct instruments for extending his sight throughout the boundless realms of space, to watch the career of the celestial bodies, "the sun that rules by day, the moon that rules by night, and the stars also;" to predict the return of comets, to explain the change of seasons, and gain knowledge regarding the surpassing grandeur and omnipotence of God, who created, and still upholds the wondrous universe.

All these, and many more extraordinary and important discoveries throughout the vast circle of the sciences, emanating from the full and accurate chemical investigation of the fact that the ashes of vegetables, heated with the sand of the seashore, combine and produce glass.

Two more simple facts, regarding wood-ashes, may be adduced as admitting of important applications: harvestmen kindle a pile of sticks upon the ground to make a fire for cooking their food; if we examine the circle of embers and ashes the next morning, we find them more damp than the soil around, whereas we might reasonably imagine that the circle of soil heated by the fire would certainly be drier than other parts.

The combustion of the wood produced carbonate of potassa, this remained in the embers and ashes of the fire, and when the heated spot cooled by radiation during the serene night, the carbonate of potassa attracted sufficient water

from the air to become deliquescent, page 180, and thus the phenomenon is explained.

If we collect the embers and ashes, and throw them into a tub filled with hard water, page 25, that is perfectly unfit for washing, as it curdles the soap on account of containing gypsum or sulphate of lime in solution, we find after the lapse of an hour that the water has become soft as the rain-water, collected before it touched the ground, page 72, that it might not dissolve any calcareous or other matter to interfere with the accuracy of an experiment made at an early period of our investigations.

The embers and ashes have rendered the hard water soft, on account of their carbonate of potash being incompatible with the sulphate of lime; the two secondary compounds, page 12, sustain mutual decomposition; the carbonic acid of the first unites with the lime of the second, to form insoluble carbonate of lime, which precipitates; whilst the sulphuric acid of the second unites with the potassa of the first to form soluble sulphate of potassa, a considerable excess of the carbonate of potassa remaining undecomposed in solution throughout the water; instead of curdling the soap and depriving it of oily matter, as sulphate of lime did, renders all the soap as soluble as it would be in rain-water.

The practical application of this fact is well known in rural districts, and weeds are burned with a slow fire to obtain their ashes, not with a fierce fire, for its heat would incite their potassa, and the silicious and calcareous matters, to combine and produce insoluble glass.

Wood, heated to redness in vessels closed against the access of air so that it cannot burn, is decomposed, its gaseous elements newly arrange themselves with part of the carbon to constitute the same acid as that which results from the spontaneous souring of fermented liquors; this is popularly called vinegar, but chemically acetic acid, which

contains a small quantity of the absolute acid, consisting of carbon $6 \times 4 = 24$ + hydrogen $1 \times 3 = 3$ + oxygen $8 \times 3 = 24$, dissolved in variable proportions of water: and is well known as a valuable antiseptic.

Then there remains in the vessels in which the wood was decomposed, a very large amount of charcoal containing the alkaline compound so recently described, but this does not interfere with its employment as a valuable fuel.

In addition to the numerous mechanical applications of wood, and its chemical employment as a source of heat, carbonate of potassa, and acetic acid, it is discovered to be capable of a most curious change or transmutation into edible matter resembling coarse bread.

This change is effected by selecting the saw-dust of the least resinous wood, that of the beech for example, washing it with water to remove all soluble matters, and then drying it in a moderately heated oven; after this treatment it is mixed with the juice of marsh-mallow, and kneaded into the form of cakes. These are baked in a highly heated oven, and then reduced to a fine powder, with the addition of a small quantity of corn flour and leaven to form a dough: this is moulded into the form of loaves, which are baked in the usual manner, and then constitute bread, more palatable and nutritious than that prepared from bran and husks of corn in times of scarcity.

Lignin admits of an extraordinary change into a substance closely resembling gum, or a soluble modification of starch; the experiment may be performed by placing small shreds of linen in an earthenware mortar with about half their weight of sulphuric acid, and rubbing these substances together with an earthenware pestle, until the linen become perfectly deorganized and dark brown;—this mixture is left for several hours, then copiously diluted with water, poured into an earthenware basin and gently warmed, and afterwards carefully filtered.

To this filtered liquid, carbonate of lime, in the form of

finely powdered chalk, is added, to combine with, and neutralize the sulphuric acid, and thus form insoluble sulphate of lime which precipitates, leaving the solution tolerably clear, and it is rendered perfectly so by a second filtration; it then possesses characters analogous to those of gum, and is employed in many of the arts as a substitute for the mucilage of that proximate vegetable principle.

If the liquid obtained by the first filtration be boiled for several hours, and the carbonate of lime then subsequently added to neutralize the sulphuric acid, the lignin of the linen shreds is converted into granular sugar, resembling in composition the sugar of grapes.

If lignin, in the form of cotton, be triturated with a mixture of equal measures of sulphuric and nitric acid, then washed with abundance of water to remove these, the cotton, when subsequently dried at a temperature of 212° , will be found highly inflammable, and capable of exploding by the contact of flame or a sharp blow; in consequence of these properties, it may be occasionally employed as a substitute for gunpowder; it is, therefore, popularly known as gun-cotton, but chemically as xylodine, from the Greek *xylōs*, wood, and is probably a nitrate of lignin.

The principal part of the winter fodder of the larger domesticated animals consists of lignin, more or less compacted, and "there is reason to believe that such lignin undergoes changes similar to those just mentioned—conversion into gum and sugar—in the digestive organs of the horse, cow, sheep," &c.; thus, by the vital functions, which cause the secretion of mysterious yet potent agents in such organs, a principle originally insoluble and inert, is transmuted into two principles which are soluble and nutritious.

These artificial transmutations of natural proximate principles by the agencies of heat, water, and acids, are conclusive to the chemist so far as they prove the numerous affinities which the three ultimate elements are capable of exerting for each other in equivalents only slightly varied;

but he acknowledges that his experiments thereon are crude and imperfect, and merely employs them as guides to his researches concerning those refined and perfect changes which similar principles are ordained to undergo in living vegetable structures by the command of Him who "has made to grow every tree that is pleasant to the sight, and good for food."

The extraordinary diversity of form and appearance displayed in the vegetable kingdom, although consisting of the same ultimate elements, and deriving sustenance from the same proximate agents, air, earth, and water, under the ethereal influence of heat and light, present magnificent examples of the wisdom and omnipotence of the Creator, who spake by his prophet,—

"I will plant in the wilderness the cedar, the shittah-tree, and the myrtle, and the oil-tree; I will set in the desert the fir-tree and the pine, and the box-tree together.

"That they may see and know, and consider and understand that the hand of the Lord hath done this, and the Holy One of Israel hath created it."

Inexhaustible are the phenomena presented by the organic kingdoms, for our observation, investigation, and reflection, and if we resume our examination regarding the proximate principle, lignin, it will be found to afford much important information, as it contains nearly half its weight of carbon as one of its ultimate elements.

Carbon, or charcoal, as it is popularly called, appears as a black porous solid, infusible, inodorous, tasteless, insoluble, and combustible. Accurate examination of its habitudes and combinations tends to the extraordinary conclusion that the absolutely pure solid combustible part of common charcoal is identical in chemical nature with the bright crystalline and valued diamond, or, in other words, that the two substances, although mechanically different, are chemically alike.

The properties of charcoal educed from wood are nume-

rous and important; it undergoes no change by the most protracted exposure to air or water, hence engineers and architects submit to the preliminary operation of charring by fire those parts of timbers that are to be employed as foundations for works in damp soils or in the beds of rivers.

Charcoal, especially when recently obtained, exerts anti-septic power upon animal food, although in an inferior degree to that of common salt, nitre, or vinegar, yet it is susceptible of much practical application; thus, dead game packed around with coarsely broken charcoal will be preserved from putrefactive taint for a considerable time; charcoal has likewise the property of withdrawing the colouring and bitter principles of many organic solutions or infusions; thus, ale filtered through a stratum of powdered charcoal, will be deprived of its amber colour, and bitter flavour.

Charcoal is principally consumed for fuel, as it burns with the emission of great heat, without the evolution of black smoke, but as its combustion depends upon its affinity for, and combination with, the oxygen of the air, it invariably produces a voluminous though invisible amount of deadly carbonic acid vapour.

Chemistry experimentally proves that one hundred pounds weight of good charcoal, during its combustion, combines with about two hundred and sixty-eight pounds of oxygen, and produces about three hundred and sixty-eight pounds of carbonic acid vapour.

One cubic foot of atmospheric air at a temperature of 50° weighs 600 grains, one foot of carbonic acid vapour at the same temperature weighs 900 grains, so that its weight is once and a half greater than that of air; accordingly, it is commonly supposed that the carbonic acid resulting from the combustion of charcoal in a chafing-dish or brazier for the purpose of warming a closed apartment, will descend and repose as a heavy stratum upon the floor, as it is popularly known to do when naturally evolved from the soil in the celebrated Grotto del Cane, and that its mephitic

effects would not be experienced by a person entering the apartment if walking upright, but this is a most seriously erroneous notion, and requires prompt refutation.

We found carbonic acid to be heavier than air when evolved by the action of hydrochloric acid upon carbonate of lime, at the same temperature as the air; we found carbonic acid to be lighter than air when exhaled from the lungs at a higher temperature than the air; and we shall find carbonic acid, as produced by the direct combustion of charcoal, to be materially lighter than the air on account of its intensely high temperature.

Therefore it does not descend and repose as a distinct stratum upon the floor of the closed apartment in which the charcoal is burnt, but in virtue of its thermal levity ascends, and, partly cooling, diffuses itself throughout the entire volume of the air of the apartment, rendering it all equally narcotic or deadly in proportion to the quantity that is produced; so that in whatever part of the room a shallow pan containing transparent lime-water be placed, its surface will soon be encrusted with a white insoluble pellicle of carbonate of lime, and thus prove the fact of the universal diffusion of the mephitic carbonic acid vapour, so that a person entering the room would immediately experience its effects whatever might be his posture, and it could not be safely entered until, by throwing the door wide open for an hour, the vapour have been permitted to escape.

The extraordinary thermal levity of carbonic acid vapour when directly resulting from the combustion of charcoal in the air, is a most important fact to be remembered, as, through ignorance of it, serious, if not fatal, results might happen; it may be strikingly illustrated by employing a small paper fire-balloon—a scientific toy almost as common as a school-boy's kite—when inflated according to the following directions:—place a small chafing-dish, containing a bright charcoal fire, upon the ground in the open air;

place a few bricks around the chafing-dish, not close together, but leave spaces about an inch wide between them, on the top of these bricks place a common red earthen chimney-pot to create a strong ascending draught of the intensely hot carbonic acid resulting from the combustion of the charcoal.

Shake out the paper folds of the balloon, hold it that its aperture may enclose the mouth of the chimney-pot, and thus collect the ascending current until the balloon be perfectly inflated; then, upon liberation, it will ascend through the cold atmosphere to a considerable altitude, and as the heated carbonic acid cools, it will lose ascensional force, become heavier than the air, and the balloon will descend to the ground.

The utility of charcoal as fuel is very great, especially in many processes of metallurgy, as, on account of its great affinity for oxygen at an elevated temperature, it not only combines with that element from the air, but from that portion which is present in the metallic ore, which thus de-oxidated, relinquishes it pure metal; this process, now technically called reduction, was known and practised in the earliest ages.

"If thine enemy hunger, feed him; if he thirst, give him drink; for in so doing thou shalt heap coals of fire upon his head."

A beautiful metaphor taken from the observance of the ancient practice of smelting ores with carbonaceous fuel, and meaning, to soften and subdue the enemy by kindness, as metals are melted and reduced by fire.

Some native metals and metallic ores were known in the earliest ages, thus in the book of Genesis it is written,—

"And Zillah she also bare Tubal Cain, an instructor of every artificer in brass and iron."

In the book of Numbers is a passage remarkable for containing the names of all the metals then in common use, viz. :—

"Only the gold, and the silver, the brass, the iron, the tin, and the lead."

In the book of Deuteronomy it is written,—

"A land whose stones are iron, and out of whose hills thou mayest dig brass."

In the book of Job occurs the following passage,—

"Iron is taken out of the earth, and brass is molten out of the stone."

Scriptural commentators agree that the Hebrew word, translated "brass," denotes the metal copper; chemical philosophers prove that brass is not an elementary metal, but a compound or alloy of the two elementary metals, copper and zinc; it has never been found native either on or in the earth; it was, and it is always made artificially by heating the metals or their ores together with charcoal; there are two ores dug from the earth, having the yellow lustre of artificial brass, but brittle, and often called "brass-stones," one of these is a sulphuret of iron, the other a sulphuret of copper, but neither can yield brass in any metallurgical operation.

Native peroxide of iron—oxygen $8 \times 3 = 24$ + iron $28 \times 2 = 56$ —and carbonate of the protoxide of iron—carbonic acid 22 + protoxide of iron 36 —are extremely abundant ores; the former occurs in nodules of a deep red colour, the latter in lumps of a dark grey colour, both have a lapideous appearance when dug from the earth; the one is therefore popularly called "red iron-stone" and the other "clay iron-stone;" both yield metallic iron when heated in contact with charcoal, and it was the fuel anciently employed in metallurgical furnaces; hence probably the origin of the expression "a land whose stones are iron."

Iron occurs native to a small extent, uncombined with any other substance; thin veins of the metal are found traversing certain rocks, thus "iron is taken out of the earth."

Iron also occurs in large masses—occasionally weighing many tons—either directly upon, or immediately below, the

surface of the earth, the metal, however, is not absolutely pure, but combined with small portions of the metals, cobalt, nickel, and chromium, but these do not materially impair its malleability, and it therefore admits of being directly fashioned into useful shapes.

These peculiar masses of iron are supposed to be of meteoric origin; some have been actually seen to fall from the atmosphere; and Eastern potentates had their favourite swords forged from such meteoric iron.

The carbonate of the protoxide of copper—carbonic acid 22 + protoxide of copper 40—is a well-known ore of the metal, it occurs native in various sized lapideous masses, of a blue or green colour, which are known in the science of Mineralogy, as the blue carbonate, and the green carbonate of copper; or the latter more commonly as malachite, or malachite stone, these are most easily reducible by heated charcoal, and yield pure metallic copper.

The carbonate of the protoxide of zinc—carbonic acid 22 + protoxide of zinc 40—is an abundant ore of the metal, it occurs native in various sized lapideous masses of a light brown colour, these are easily reducible by heated charcoal, and yield metallic zinc; this metal was unknown to the ancients; for, being extremely volatile, it escaped their detection, they well knew its abundant ore, but did not suspect it to contain a metal; they regarded the ore as a mere stone gifted with the power of changing red copper into yellow brass; it is known to miners of the present day as “calamine stone.”

Malachite stone, and calamine stone, thrown together in furnaces containing burning charcoal, the heat would expel the volatile carbonic oxide and carbonic acid, and educe the oxides of copper and zinc; the charcoal of its pure carbon would then combine with the oxygen of both oxides to produce volatile carbonic oxide and carbonic acid, and to educe both metals; these would combine to a certain extent and produce brass, which, in the unrefined operations of ancient

metallurgy, might easily be deemed a metallic educt of the stone employed : hence, probably originated the expression —“brass is molten out of the stone.”

Many passages in the first books of Holy Writ, prove that in the earliest ages much was ascertained regarding the art of working metals ; mention is made of the “iron furnace” and of iron, as employed for making swords, knives, axes, and tools for cutting stones ; likewise of other metals lavishly employed in the construction of the Tabernacle and the Temple.

The metals are distinguished from all other substances by being the best reflectors of heat and light, the best conductors of heat and electricity, and by their peculiar lustre ; the metals of most common occurrence have great specific gravity.

In consequence of the good conducting power even of the most common metals they are invaluable for the construction of vessels in which water may be converted into vapour, to constitute the motive power of the steam-engine.

In vessels constructed of metals, culinary operations can be conducted more perfectly and economically than in utensils formed of earthenware or other imperfectly conducting materials, and if it were not for the metals we should be in the condition of those savage tribes who are yet unacquainted with them in any useful quantity, and who therefore make rude vessels of the thin bark of trees, to contain water in which they place food, and then heat the water to its boiling point by the successive immersion of red hot stones.

Upon tracing lignin as a chief constituent of the bark of trees, Chemistry discovers another example of the infinite wisdom and the beneficent care of the Creator for the preservation of their vital functions throughout all the changes of the Four Seasons.

Lignin is an extremely bad conductor of heat, and thus in the form of an external covering of bark, prevents the sap

of trees from disturbance in the regularity of its circulation by sudden changes in atmospheric temperature, and secures it the degree most congenial to the performance of its vital functions.

If the bark were not thus created of bad conducting material, trees and plants would suffer from the heat of summer and the cold of winter; from the latter more especially, as it would invariably cause their death by the freezing of the sap, a phenomenon even sometimes observed during an extremely rigorous winter; but it can be prevented, in many instances, by enveloping the trunks of trees with a thicker artificial coating of lignin in the form of matting, or bands of hay and straw.

When tropical plants are transported to cold climates, we artificially clothe them with similar bad conducting materials, to prevent them from suffering by the sudden transition of temperature, the same as we endeavour to protect ourselves against its effects by putting on an extra garment in passing from hot to cold weather.

By keeping a thermometer in a hole bored in a sound tree during hot weather, it constantly indicated a temperature several degrees below that of the atmosphere, and during cold weather a temperature several degrees above that of the atmosphere; and another wonderful fact was also discovered, namely, that sap drawn from the tree would freeze at the same temperature as pure water, 32° , whilst the sap circulating in the tree, under vital agency, would not freeze until reduced to 15° , a temperature 17° below the freezing point of water.

The dense foliage of trees consists principally of lignin, and by its very imperfect conducting power forms the cool shade which at noon-day is so eagerly sought out by men and animals from the piercing rays of the sun.

Chemistry ascertains that during the ripening of fruits in autumn they tend in all cases to the production of carbonic acid; and, as in the case of seeds, which will not germinate

unless carbon escape from them, page 87, so in this of fruits, they will not ripen unless they can relinquish a portion of their carbon as carbonic acid; indeed they will rapidly die and rot if their functions in this respect be prevented.

When fruits rot, they first change a portion of the oxygen of the air into carbonic acid, and then emit carbonic acid ready formed, so that during autumn both the ripening and decay of fruits become sources of carbonic acid in the atmosphere: the leaves of healthy plants have the power of decomposing this carbonic acid, and of elaborating its carbon into matters conducive to their vitality under the direct influence of solar light.

Chemistry proves that no inorganic substances, either naturally presented or artificially formed, are suited for the support of animal life, although they may actually contain carbon, hydrogen, oxygen, and nitrogen, which are the ultimate elements of organic bodies.

To constitute food, these elements must have been previously subjected to the laws and powers of vitality, either in the animal or in the vegetable kingdoms; in other terms, food must consist of organized matter; all attempts to form food by the direct presentation of its elements to each other, are perfectly futile.

A judicious and varied admixture of animal and vegetable food, prepared by culinary operations, is absolutely indispensable for the proper sustenance of human life; but to obtain such food, cattle must be cherished, and ground must be tilled.

Grain bearing vegetables, the chief of which are wheat, barley, oats, maize, rye, rice, millet, beans, and peas, have never been discovered in a natural, or as it is commonly called, a wild state of growth; they all require artificial cultivation by human labour, and thus powerfully illustrate the Sacred truth, that the fallen destiny of man is "to till

the ground from whence he was taken, and in the sweat of his face that he shall eat bread."

In former times, when the frequent occurrence of civil and foreign wars distracted men from the labours of husbandry, scarcity of food commonly resulted, and famine overspread the land; but since the great cessation of such sanguinary strifes, men have "beat their swords into ploughshares, and their spears into pruning hooks," and returned diligently to agricultural toil, aided by the observations, experiments, analogies, and truths of chemical science, and thus rendered capable of reflecting and reasoning upon natural phenomena, and of bringing philosophical principles to bear upon the succession of crops and the nurture of cattle, so that a general scarcity of food is seldom known.

England, supremely blest with "every good and perfect gift" from the bounteous hand of God, presents a brilliant example of the utility of science judiciously applied to increase the advantages, comfort, and benefit of man, yet gloom occasionally overshadows it in the midst of "garners full, and affording all manner of store;" there being not only "complaining in our streets," but misery, destitution, prostration of corporeal, and aberration of mental faculties, from the inability of poverty to obtain a scanty pittance of the generally abundant food, and dreadful above all, cases of lingering death from absolute starvation.

"Blessed is he that considereth the poor; the Lord will deliver him in the time of trouble."

"The rich and poor meet together; the Lord is the maker of them all."

The philanthropist adorns his country with temples of Christian charity and benevolence for the reception and alleviation of the sufferings of his fellow-men, and upon visiting these meritorious works, in many cases the physician can but too surely point out that present disease, was caused by previous starvation, and that the restorative now required

is generous food, rather than the "medicines out of the earth, of which doth the apothecary make a confection," although such may need occasional prescription by the physicians, for "there is a time when in their hands there is good success."

The exalted science of Medicine enrolls amongst its followers many of the best and greatest men of the age, men of expanded sentiments and pure philanthropic feelings towards their fellow-creatures, be they high or low, rich or poor; men who are constantly bent upon healing the sick, comforting the afflicted, alleviating the vast and terrible complications of human sufferings; men who humbly, yet steadfastly following the footsteps of their Divine Master, are constantly "going about and doing good."

For the proper formation and renewal of the solid and fluid portions of the human body which contain nitrogen, a due supply of food also containing that element—especially in the form of flesh—is imperatively demanded; for it is an established fact, that animals fed entirely upon proximate organic principles void of nitrogen, invariably sink under such diet; and if its use be prolonged, they ultimately die with all the symptoms which are attendant upon death from absolute starvation.

Although nitrogen is abundantly present in the atmosphere, Chemistry discovers that the element is never withdrawn from thence for elaboration into the human body, but is always derived for that purpose from the organic food taken for the sustenance of life.

Blest with health and strength, fortunate indeed is the man who "goeth forth unto his work and to his labour until the evening," and by the exercise of his mental and bodily faculties can earn a sufficient sum for the purchase and preparation of a due share of the wholesome animal and vegetable food which is necessary for the proper support of his existence, and thus prevent him from falling beneath the hands of those economical magnates who

appear to hold scientific fact and common sense in such low estimation as to make an attempt to force on his belief that "raw vegetables and water are conducive to health and longevity;" who would dole him forth a minimum of meagre food for the barest support of the frail earthly tenement of his immortal soul, until "the wheel at the fountain is broken," and the vital essence escaping from temporal wrong and oppression, seeks for eternal mercy and repose in the bosom of its God.

Chemistry proves that dead organic substances, which contain the same ultimate elements as the living human body, are alone fit for its food, and that the power of vitality exerts a series of the most wonderful and inimitable changes upon such dead matter, in rendering it subservient to the fulfilment of its destined office.

Food, after mastication and mixture with the secretions of the salivary glands, and transposition by deglutition into the stomach, meets a peculiar secretion called the gastric juice, which is a powerful solvent of dead matter—and such food must be—and during digestion reduces it to a semi-fluid state, called chyme.

Chemical analysis of the gastric juice does not materially enlighten experimenters regarding its solvent powers; it is found to contain hydrochloric acid, probably formed by the agency of the common salt that is naturally contained in all proper food and drink, or taken therewith as a condiment; but the small proportion of this acid, and of other acids and peculiar principles that can be detected, are insufficient to account for the solvent action of the gastric juice upon food, and it must be referred to the incomprehensible power of vitality.

Chyme, the first product of digestion, may be considered as intermediate with the original food and arterial blood; it proceeds from the stomach into the small intestines, and there meets with another extraordinary secretion termed bile, which mingles with it, and very probably confers

some alkaline matter; the contact of bile and chyme separates the latter into two portions, one of which passes into the large intestines, and is ultimately voided as excrementitious, whilst the other appears as a milk-white fluid termed chyle, which is rapidly absorbed by a peculiar set of vessels termed the lacteals, and by them transmitted to the thoracic duct, and from it to the venous system.

Upon entering the venous system the whiteness of chyle is succeeded by a dark purple colour, referrible, as it would appear, to the absorption of a superabundance of carbon, which, if retained in the system, would prove hurtful.

This purple chyme or venous blood is received by the right cavity of the heart, which wondrous organ by regular pulsations transmits it to the lungs, where, extremely diffused by their peculiar membranous structure, it is exposed to the influence of the inhaled air, and the extraordinary changes immediately ensue which have been mentioned, page 83, when speaking of the action of animal respiration upon the atmosphere.

The blood, thus deprived of its excess of carbon, returns to the left cavity of the heart, with a florid red colour, as arterial or perfect blood, containing a peculiar colouring principle called hæmatosyn, having iron as one of its elements, page 49, and two proximate principles already mentioned as fibrin and albumen, and a small proportion of saline matters; the blood thus constituted is endowed with the power of circulating throughout the system for the secretion of new parts, and for the removal of such as have performed their functions.

Whilst circulating throughout the system the blood is a homogeneous fluid, but upon removal therefrom it separates into a solid and a fluid portion, the former containing the colouring principle and fibrin, the latter the albumen, but all combined with a large per centage of water.

The human mind has always a tendency to seek into incomprehensible matters; but incessant and laborious as

have been the researches regarding the physical cause of the functions of digestion, nutrition, respiration and animal heat, very little of real importance has been discovered beyond the above statement, "though a wise man think to know it, yet shall he be not able to find it."

Confident assertion is the imposing mask which is commonly assumed by ignorant pride, and unhappily, examples are to be found of men "wise in their own conceit," led by their vanity and love of temporary notoriety attendant upon the announcement of a novel doctrine, who do not hesitate to express themselves regarding the recondite works of God in terms of gross irreverence, which they would fain ingraft upon the pure and unsullied language of science.

Neglecting the Scriptural truth that "God created man in his own image, in the image of God created he him," and "breathed into his nostrils the breath of life, and man became a living soul," grasping at the experimental fact that heat is evolved during combustion, they maintain that the heat of the animal body depends upon the burning of the carbon of food, and complacently state that the "human frame is an apparatus eminently fitted for combustion, or a species of natural stove."

The body of man "is fearfully and wonderfully made, in knowledge too excellent for attainment,"—no true philosophers would denote a recondite work containing a portion of the Divine essence, by the common name of a laboratory furnace for the combustion of coal.

The seeds committed to the earth a few months since, watered by the showers of spring, warmed by the sun of summer, have attained their perfect structure during autumn, and brought forth some ten-fold, others sixty-fold, according to the nature and situation of the soil.

For example, if we now proceed to the plot of ground where the beans were first cast, for affording us the means of investigating the phenomena of germination, we shall find such of them as remained undisturbed, have grown up

into perfect plants with luxuriant foliage, and from the intervening stems are hanging numerous heavy pods, each containing, not one single bean, but six, seven, or eight beans all precisely identical in their physical and chemical characters with those originally committed to the earth, and into which, by the bursting of the ripe pod, they would ultimately fall, and remain dormant during the approaching winter, then germinate upon the return of spring, flourish throughout summer, ripen during autumn, and then again, as now, display a manifold store.



Fig. 54.

We thus find the existence of most plants to be dependent for its continuance on an inherent law or principle of producing a seed similar to that from whence it sprung; the perfecting of this seed is the grand object of the various processes and actions which take place from germination, throughout growth, to maturity, and when it is accomplished the plant dies, and mingles with the earth.

Occasionally the leaves only die, and fall upon the earth for slow yet sure transition into food for future plants, whilst the stem and branches, though denuded, remain unharmed and dormant throughout the rigour of winter, and awake to the full exercise of their vital functions for the reproduction of foliage, flowers, and fruits, as spring, summer, and autumn appear in unerring and ceaseless change.

How miraculous are the foregoing phenomena of the transmutations consequent upon the death of proximate principles, and the birth of others in organised structures at the direct command of their Creator! how pure, how

exalted are the feelings of faith and comfort inspired by their contemplation and investigation! they direct our thoughts from now to hereafter; they are alluded to in Scripture as emblematical of the "resurrection of the dead," in those sublime words which have been selected to constitute a portion of the most impressive of all Church services,—“The Order for the Burial of the Dead,”—

“But some man will say, how are the dead raised up? and with what body do they come?

“Thou fool, that which thou sowest is not quickened except it die;

“And that which thou sowest, thou sowest not that body that shall be, but bare grain, it may chance of wheat, or of some other grain :

“But God giveth it a body as it hath pleased Him, and to every seed his own body.

“So also is the resurrection of the dead.”

In this general inquiry it is impossible to touch upon all the extraordinary matters that are presented to our notice during the season of autumn; the mere examination of the proximate principles of vegetables would, if fully carried out, occupy far more space than is here devoted to the phenomena of all the four seasons.

The rich and varied produce of corn-fields, vineyards, orchards, and gardens, have been gradually elaborated by the recondite powers of vitality from the earth, the waters, and the air, directed by the hand of Omnipotence from the dawn of spring, throughout the noon of summer, into the evening of autumn; “the trees of the field have yielded their fruit, and the earth has brought forth her increase,” for the welfare and comfort of man during the approaching night of winter.

In reference to the power and goodness of God, who fixes the mountains, calms the seas, and refreshes and fertilizes the earth, providing abundance of necessities for the use of man, well does the inspired Psalmist exclaim with rapture :—

"Thou crownest the year with thy goodness; and thy paths drop fatness;

"They drop upon the pastures of the wilderness, and the little hills rejoice on every side.

"The pastures are clothed with flocks; the vallies also are covered with corn; they shout for joy, they also sing."

During autumn we frequently see upon meadows, circles of green much brighter than that of the surrounding grass; these are popularly known as "fairy-rings," and are probably due to the growth of a fungus, which, dying away every year, manures the soil, on account of containing nitrogen—and therefore approximating in composition to animal matter—making it extremely rich, upon which the grass then grows in its season more luxuriantly than upon other parts of the meadow; these rings, therefore, annually increase in size, and in many localities they present a very remarkable appearance.

Slight frosts are common towards the close of autumn, and therefore tender plants require protection by matting or other bad conducting material to keep in their vital heat; at this season also may be observed in the fields, marks of footsteps which appear to have scorched the grass like heated iron; this phenomenon, which was formerly regarded with superstitious dread, can now be explained upon very simple chemical principles.

Upon the grass becoming crisp by frost, it is exceedingly brittle, and the foot of a man, or even a child, is sufficiently heavy to break it down, and to kill it; therefore, when the sun has thawed the frosty rime from the fields, these foot-tracks appear brown and bare, in the midst of the surrounding and flourishing green grass.

The sun now declines in splendour and heat, the atmosphere becomes chilled, and the leaves of trees assume an infinite variety of hues, thus presenting beauties even in their decay; these well known autumnal tints are presumed to depend upon peculiar acid matters now forming in the

leaves, which, acting upon their specific principles, that during summer caused a reflection of green light, so modify them as to produce a reflection of red and yellow light, and various intermixtures of coloured rays.

The sight of a vast forest, thus variously tinted by the rays of the setting sun, is indeed magnificent; but the foliage soon loses its vital functions; the fall of the leaf arrives, and then the chill winds denude the trees, sweeping down their leaves to mingle with the earth, there to elaborate nutriment for the stems they once adorned.

Such are a few of the principal phenomena of autumn which admit of interpretation through the science of experimental Chemistry, and as the season draws to its close, the frequent occurrence of frost, warns us of the approach of that of winter.

During the dark and dreary reign of this, the last of the four seasons, we shall still have to extol the power and appreciate the goodness of the Almighty in providing for the welfare and protection of His creatures, although "the waters are hid as with a stone, and the face of the deep is frozen."

CHAPTER IV.

Winter.

DECREASING days, gathering vapours, falling dews, piercing winds, and chilling frosts, conclude the train of departing autumn, and commence that of approaching winter.

The most remarkable chemical phenomenon of winter, is the transition of water from the liquid to the solid state, and therefore its investigation will principally engage our attention.

Chemistry ascertains that all substances expand when heated, and contract when cooled, with the exception of water; it expands when cooled to a certain degree; this departure from a law so general, is productive of the most beneficial effects throughout the Creation; these will be fully understood and appreciated by making the following experiments, bearing in mind that the popular terms heat and cold are merely relative, the one denoting an elevation, and the other a depression of temperature.

Provide a flask with a long narrow neck, yet sufficiently wide to admit of the introduction of the delicate thermometer of the hygrometer, page 228, when detached from its standard and suspended by a fine string; pour water, at

the temperature of 80° , into the flask until about two inches of the neck remain unoccupied; then introduce the bulb of the thermometer to dip just below the water; secure it from slipping farther down by winding the string around the neck, on which make a mark with a fine triangular file, exactly coincident with the level of the water therein; lastly, lift the flask into a two-quart earthen jug, containing a mixture of one pound of finely powdered ice and one pound of salt, previously rubbed together in a earthen bowl; this forms a ready source of cold—for a reason to be given—and is well known to confectioners as a freezing mixture.

As the water in the flask cools from 80° , it will contract in bulk, and fall in the neck; let the thermometer be closely watched, the water will continue to contract, until it attain the temperature of 40° , then it will slowly expand, and rise in the neck of the flask until the thermometer indicate 32° , and then the water will congeal or freeze; mark the level of the newly formed ice with a file upon the neck of the flask, then immediately lift it from the cold mixture, wipe its exterior perfectly dry, and place it to stand upon a ring, as directed in former experiments.

The knowledge which emanates from an accurate investigation of the experiment now performed, is of great importance and interest, and may be thus stated;—when the water contracts by depression of temperature to 40° , it is technically said to attain its maximum of density, the expression implying if it be cooled below 40° , or heated above 40° , its contraction in the one case will be similar to its expansion in the other.

The ice in the flask is now thawing on account of gaining heat from the surrounding atmosphere, and after the lapse of some hours the thermometer will indicate when the water resulting from the thawing has risen from 32° to 40° —its maximum of density—as it becomes warmer it will expand, and upon attaining 48° it will rise to the same mark, or will be of the same bulk, as it was at 32° , or

in other terms, at 8° above 40° , and at 8° below 40° , water is of the same bulk.

With this incontrovertible experimental fact, Chemistry is enabled to venture upon an interpretation of the physical cause of the transition of flowing water into solid ice during the natural cold of winter.

Let us select a fresh water lake for the purpose of fully exemplifying these important matters;—in winter the earth is warmer than the air, page 109, consequently the water of the lake has heat abstracted by the cold wind that blows over its surface, the water thus cooled, has its specific gravity or density increased, and descends, whilst warmer water of lesser specific gravity or density ascends to undergo a similar abstraction of heat, and to sustain a similar increase of specific gravity or density in its turn; thus descending and ascending, or convective currents are established and continued; until the entire bulk of the water of the lake attain the temperature of 40° , or attain its maximum of density, the temperature and the liquidity being alike congenial to aquatic beings.

The cold wind continues to blow over the surface of the lake, continues to abstract heat therefrom, but the water does not continue to contract, does not continue to increase in density; on the contrary, it expands, and decreases in density, and although colder than the water beneath, actually floats upon the surface.

This stratum of light cold water cannot communicate depression of temperature from the cold wind to the warm water upon which it floats, because it has little or no conducting power, page 55; and its convective power is at an end, it therefore remains floating until cooled by the wind to 32° ; at this temperature it has parted with so much heat, or, in other words, it is so chilled, that it can no longer remain liquid, and therefore changes into solid ice.

Over this newly formed solid surface the wind may continue to blow with its utmost intensity of winter cold, but

the ice shields the liquid water from the chilling agency, and preserves it immutably at 40° , whatever may be the degree of cold of the external atmosphere, for ice is a non-conductor. The temperature of the ice may fall many degrees below 32° , but that of the water beneath will never fall below 40° ; accordingly, fishes dwell securely in the warm liquid depths, until the warmth of spring dissolves the icy shield, and then they rise to the surface of the emancipated waters. Had the Creator ordained that water should thoroughly cool to its freezing point, by direct conduction of cold from the ambient air, then upon the approach of winter it would congeal into one entire and solid mass of ice, to the utter destruction of aquatic beings.

But the Creator, in His transcendent power and beneficence, has ordained water to possess habitudes with elevation and depression of temperature which are perfectly different, or anomalous to those of other liquids; it is ordained to expand at an immutable degree, and, therefore, the resulting ice, although solid, is lighter than the liquid water upon which it floats, and protects from congelation; thus, "By the breath of God frost is given, and the breadth of the waters is straightened;" thus "the waters are hid as with a stone;" thus are they "clothed with ice as with a breastplate," to defend their living inhabitants from the cold atmosphere of winter.

This miraculous transition of flowing water into solid ice, is not an abrupt or sudden phenomenon; if it were, vast and incalculable derangement of the economy and order of the whole Creation would inevitably ensue; on the contrary it proceeds with a degree of slowness and regularity invariably proportionate to the depth of the water that is exposed to the cold atmosphere of winter.

Considerable time elapses before the entire bulk of water is cooled to 40° by convective currents; and until it be so cooled, and its expansion effected by continued cold it will not freeze.

Chemistry discovers that some deep lakes are never frozen, because the cold of the ambient air has been unable to establish the full agency of convection throughout the vast bulk of their waters, even during the most severe and protracted winter; again, when a sheet of ice has formed upon more shallow waters it increases its mass with extreme slowness, and rarely gains a thickness at all proportionate to the depth of their main bulk; it is, comparatively speaking, a thin film, because it is incapable of rapidly conducting depression of temperature from its upper to its lower surface.

Rivers and streams resist congelation for a longer time than lakes and pools, because their tides and currents interfere materially with the establishment of the agency of convection, and the water of the ocean in temperate climates still more effectually resists congelation on account of its enormous bulk, extreme depth, extensive agitation, and large quantity of saline matter, this alone will prevent it from freezing until its temperature fall to 27° , that is, 5° below 32° , the freezing point of fresh water.

Within the arctic circle the surface of the ocean is seldom warmer than 27° , therefore in the decline of summer it soon attains such temperature, and congelation proceeds so rapidly that in the space of a few hours, a sheet of ice of an inch in thickness is formed, and, the cold continuing, this increases until it attain a thickness of several feet, and covers the waters with an impenetrable barrier.

An experiment can be made to prove that saline matter present in water, will cause it to resist congelation at 32° :—add common salt to half a pint of water as long as it will dissolve, this is indicated when, after stirring or shaking the solution, a considerable quantity of the salt precipitates to the bottom of the vessel in which it is contained; pour off the liquid, and if necessary let it run through a piece of fine muslin to render it clear; it is strong brine, or, chemically speaking, a saturated solution of chloride of sodium.

Select a thin vial that will hold all, or a great part of this solution, also another that will hold an equal bulk of water, place these vials in a mixture of ice and salt, and thus expose them to the same degree of cold ; the water will freeze at 32° , but the brine will remain liquid at this temperature and even at many degrees below it, as the introduction of the bulb of a thermometer will prove.

Chemistry by discovering that saline matter present in water causes it to resist congelation, teaches us to regard the ocean as an enormous magazine of heat, enacting an important part in yielding that imponderable agent for the mitigation of the inland cold of winter, page 212.

Several curious and instructive experiments can be made regarding the phenomenon of the congelation of fresh-water ; —in the first place provide a cylindrical glass about three inches in diameter, and two feet in height, open at one end, and closed at the other by a broad welt or foot upon which it will stand firmly.

Water at 40° , in sufficient bulk to fill the glass, is next required ; this can be readily obtained by gradually adding snow or finely powdered ice to hot water contained in a basin, and as the thawing proceeds, testing the diminution of temperature until it arrive at the proper degree ; then pour it from the basin into the glass until it rise within four inches of the brim ; next introduce a few lumps of clean ice which will float upon the water, and at the same time raise its level nearly coincident with the brim of the glass, allow this arrangement to remain for a few minutes that the ice may slowly thaw.

Carefully withdraw the delicate thermometer from the neck of the flask used in the first experiment upon the congelation of water, page 305 ; and by the string let it descend through the water in the tall cylindrical glass until it rest at the bottom, the temperature will be 40° ; then gradually draw the string to raise the bulb of the thermometer into the water resulting from the thawing of the ice ; its en-

trance into this peculiar stratum of water will be known by its indicating a temperature of about 33° , thus proving that the ice-cold, or nearly ice-cold water, is actually lighter than the warmer water at 40° , and that it is floating on the surface; the extraordinary and important conclusion is thus obtained, that within certain ranges of temperature, cold water will float upon warm water, whereas the reverse is the case with all other liquids.

This experiment being concluded, the water may be poured from the cylindrical glass; then, in farther illustration of the lightness of ice-cold water and ice, and the non-conducting power of ice and water, another simple arrangement can be made.

Select a well-shaped flower-pot, the upper part of which is from six to seven inches in diameter; then with a round rasp, enlarge the aperture at its lower part, until it will admit the upper part of the cylindrical glass when gently thrust therein, to a sufficient extent for its brim to stand a quarter of an inch above the level of the brim of the flower-pot.

A piece of broad tape, about three feet long, must be wound tightly around the part of the glass that protrudes from the lower part of the flower-pot, and then coated with a thick mixture of plaster of Paris and water, to unite the surfaces firmly, and make a water-tight joint; when the plaster has hardened or set, the glass may be placed to stand upright as at first, but supporting the flower-pot around its upper part, and to prevent the arrangement from falling over by an accidental shake, a heavy brick must be placed on the opposite surfaces of the welted foot of the glass.

Thrust a bunch of cotton into the mouth of the glass, then fill the space around it in the flower-pot with a freezing mixture; remove the bunch of cotton, take care that none of the mixture fall into the glass, and pour water at common temperature into it, until within an inch of its brim.

This arrangement will enable us to imitate artificially and rapidly, upon a microscopic scale, the phenomenon that proceeds, naturally and slowly, upon a gigantic scale during the winter, because in both instances, the source of cold is applied at the surface of the water, the only difference being, that in the artificial instance it is derived from the mixture of ice and salt, and in the natural instance, from air of an extremely low temperature.

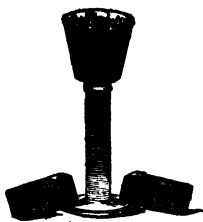


Fig. 55.

Take the suspended thermometer, immerse it at different depths of the water from time to time, and remark that it indicates the power of the mixture in reducing the temperature uniformly to 40° ; because those portions of water in immediate contact with the source of cold, lose heat, contract, become heavier and descend, whilst portions more remote being warmer, ascend; they in turn lose heat, contract, become heavier, and descend, convection—not conduction—is thus established, until the entire bulk of the water be reduced in temperature to 40° , its maximum of density.

Having attained this maximum of density, the process of further cooling is no longer extended throughout the entire bulk of water, but is confined to the portion in immediate contact with the source of cold; this remains constant, but in place of still producing contraction and increase of the density of the water, now induces its expansion and decrease of density; this will be immediately detected by the rising of the water nearer to the brim of the glass.

Thus the cold water is lighter and floats upon that which is warmer and heavier; the thermometer which indicates 40° at the bottom of the glass, will soon indicate 32° at or near the top; when this happens, the water can no longer

remain liquid ; but will congeal into a solid cylinder of ice, extending from the top to the bottom of the mixture, whilst the water from the lower part of the flower-pot to the base of the glass, will remain liquid, because it is of the higher temperature of 40° , and incapable of conducting depression of temperature thereto, from the ice at 32° upon its surface.

If the arrangement be now dismantled, by pouring away the freezing mixture, and wiping the outside of the glass cylinder dry with a cloth, not only will the danger of its fracture be prevented, but the mass of ice that it encloses will be more distinctly seen.

If the source of cold be applied around the lower part of the glass cylinder when filled with water at common temperature, the effect is very different, for the cooling of the water below 40° renders it lighter, it ascends whilst warmer water descends, becomes cooled in its turn and ascends ; thus convection is established throughout the entire bulk of the water, or thus its entire bulk is cooled to 32° , and it will become solid ice throughout its entire bulk ; an effect limited to the mere surface of the water in the experiment recently performed, and it—as stated—represents what naturally happens in winter when the cold is always superficial, and ice being lighter than water, always floats upon its surface.

If the weight of a given bulk of water be equal to 1000, the weight of a similar bulk of ice will be equal to 940, in other words, the inherent, particular, or specific weight of the ice is less than the inherent, particular, or specific weight of the water.

Although the subject of specific weight, or more commonly specific gravity, has been already mentioned, pages 23, 27, it is of sufficient interest and importance to demand farther consideration at this stage of our investigation, as it will tend to the additional elucidation of many wonderful phenomena which have been described, and of others which remain for examination.

Suppose a measure so accurately constructed that its ca-

capacity is exactly equal to 1728 cubic inches or one cubic foot suppose the tare of this measure to be taken, and that it be afterwards filled with rain-water at a temperature of 62° , this bulk, measure, or cubic foot of water will weigh 1000 ounces avoirdupois; this weight is adopted as a standard of unity, because water may be obtained sufficiently pure and abundant for all practical purposes.

If the rain-water—nearly pure—be removed from the cubic foot measure, and its place supplied with sea water, 28 ounces will generally be required as an addition to the 1000 ounces, before an equilibrium of the scales is effected, so that the weight of one cubic foot of sea water will be 1028 ounces.

If the sea water be removed, and a solid block of ice be accurately wrought to fit the cubic foot measure, 88 ounces must be taken from the 1028 before a balance is again effected, so that the weight of one cubic foot of ice will be 940 ounces.

Therefore sea water is heavier, and ice is lighter than water; the numbers 1028 and 940, directly express their relative weights to it, or technically, their specific gravities, the one being 28 thousandths heavier, and the other being 940 thousandths lighter than water, or more commonly expressed by decimals as thus: specific gravity of water = 1.000, sea water = 1.028, ice 0.940.

Having fixed upon water as a standard of unity, and proceeding to ascertain the specific gravities of various liquids and solids, it is found that very few of them are exactly coincident, for example, spring water, containing a very small amount of chloride of sodium and sulphate of lime, has a specific gravity equal to 1.001; water of the Dead Sea, containing much chloride of sodium, chloride of magnesium, and chloride of calcium, 1.211; water saturated with chloride of sodium, forming brine, 1.220; these differences in the specific gravities being dependant upon the fact of a greater actual weight of matter being contained within the same bulk, in some cases than in

others; thus all saline substances, such as the chlorides of sodium, magnesium, and calcium, the sulphates of magnesium, soda, and lime, when held in solution by water, increase its specific gravity until it be saturated and can dissolve no more.

Thus spring water is a weak solution, its specific gravity barely exceeds that of water; sea water is a strong solution, water of the Dead Sea a stronger solution, and these both exceed the specific gravity of spring water; whilst brine, which is the strongest solution of them all, exceeds even the specific gravity of the water of the Dead Sea.

The fact that equal bulks of different liquids have different weights, may be experimentally illustrated; take the tare of an ounce narrow-mouthed vial, then fill it with water, ascertain the weight of such water in grains, pour it away, fill the vial with sea water, ascertain its weight, which will be materially greater than that of the water; then empty the vial, and fill it with brine, ascertain its weight, which will be materially greater than that of the sea water; throw away the brine, fill the vial with alcohol, ascertain its weight, it will be materially less than that of any of the other liquids; lastly, remove the alcohol, supply its place with mercury, ascertain its weight, and it will be found many times greater than that of the other liquids, even supposing they were all placed together in the scale.

If the experiment be made with mercury, a very common pair of scales should be employed, because its extreme weight would either break the strings or bend the beam of a delicate balance, and render it useless: a notion of the weight of the liquid metal may be formed from the fact, that, if a vial capable of containing one ounce of water be filled with mercury, the metal will weigh thirteen ounces and a half.

To ascertain the specific gravity of any of these liquids in relation to that of water as a standard, divide the weight of each decimally by the weight of the water that the vial will hold; thus, suppose it will hold 425 grains of water, and it be found to hold 350·5 grains of alcohol and 5737·5

grains of mercury, then $350.5 \div 425 = 0.824$ the specific gravity of alcohol, and $5737.5 \div 425 = 13.5$ the specific gravity of mercury.

In the chemical laboratory the tare of a thin globular bottle that will hold exactly 1000 grains of water at 62° , is placed with 1000 grain weights in one scale, and the bottle filled with any liquid placed in the other, then by the addition or subtraction of grain weights to or from the 1000 grains, until an equilibrium be effected, the specific gravity of the liquid, whether above or below that of water, will be immediately ascertained without the trouble of the foregoing arithmetical formulæ; this contrivance is called a 1000 grain bottle, or more commonly a specific-gravity bottle.

A very homely, yet tolerably accurate method is often adopted for ascertaining when brine is sufficiently strong for the preservation of meat; it consists in the fact that an egg will sink in spring or river water, but will float when as much common salt is added as such waters can dissolve; the egg thus becomes a hydrometer or measure of liquid strength, and upon this simple principle a refined instrument bearing that name is constructed for ascertaining the specific gravities of saline solutions, acids, worts, and spirituous liquors with celerity and accuracy.

The accompanying engraving shows the usual form of the hydrometer, which is constructed of glass or metal, according as it is intended to be employed for ascertaining the specific gravities of corrosive or neutral liquids.

It consists of a hollow bulb, generally about the size and form of a hen's egg, with two stems of unequal length, the longest, about nine inches, proceeding from the larger, and the shortest, about four inches, from the smaller end; this latter has a small bulb about half an inch in diameter at its extremity, and is either originally made sufficiently heavy, or is ballasted within by a globule of mercury, or a few small lead-shot, that



Fig. 56.

it may cause the larger bulb and stem to float upright when plunged into a liquid, the same as the piece of lead that is nailed on the keel of a toy-boat, causes it to float with its hull and mast upright on the water of a pond.

A cylindrical glass about twenty inches high, and of diameter sufficient to admit the large bulb of the hydrometer with great facility, having a lip at its brim for the convenience of pouring, and a heavy welted foot for its steady support, is called the hydrometer glass; it is to contain the liquid, the specific gravity of which is to be ascertained.

Suppose the glass contain water to within two or three inches of its brim, and the hydrometer with the smallest bulb downwards be immersed therein, the instrument will sink until the large oval bulb and part of the longer stem become immersed; a mark is therefore made upon the latter, coincident with the surface of the water; this is a standard mark, and indicates the depth to which the hydrometer will always sink in water having a specific gravity of 1000 at 62° of temperature; for at such temperature specific gravities are always taken, page 27, or else referred to it by calculations; a number of equal divisions being marked above and below this standard mark, the depth to which the longer stem sinks will show if any other liquid into which the hydrometer be plunged is heavier or lighter, or has a specific gravity above or below that of water.

Thus in alcohol, the instrument would sink and submerge nearly the whole of the longest stem—the same as an egg would sink in spring water—whilst in the water of the Dead Sea it would rise and emerge the standard mark considerably above the liquid surface—the same as an egg would float upon brine—and by repeated immersions of the hydrometer in liquids and solutions, the specific gravities of which have been previously determined by accurate weighing in a specific-gravity bottle, real specific gravities may be marked on the stem, if of metal, or on a paper scale

included therein if it be of glass, and can thus be immediately read off, with sufficient accuracy for all ordinary purposes.

As another illustration of the principle of the hydrometer, it may be remarked, that it is much easier for a person to swim in sea water than in river water, because the human body, like the egg on brine, is buoyed up in a greater degree in the one case than in the other; indeed if a boat were so laden as to float with safety on the water of the ocean, it would sink at its arrival on the water of a river.

This fact may be proved by placing a toy-boat upon brine, next gradually and evenly loading it with sand, until it float with its gunwale exactly level with the surface of the brine, then, carefully lifting the boat therefrom, and gently placing it upon river water, through which it will instantly sink.

Another experiment may be performed in illustration of the important subject of specific gravity: place the pipe of a wine-strainer in an ale-glass, that it may quite touch the bottom, then pour through it brandy sufficient to occupy half the capacity of the glass; having done so, slowly pour down water sufficient to occupy the other half, gently remove the wine-strainer, and the difference between the specific gravities of the two liquids will be strikingly displayed by the coloured brandy floating on the colourless water; and if a lump of white wax, about the size of a hazel-nut, be placed on the brandy, the wax having a greater specific gravity than it, will sink, but having a less specific gravity than the water, will float upon its surface beneath the brandy.



Fig. 57.

Another experiment yet more remarkable may be performed, and although its preparation requires some time and patience, it will amply repay both, by the curious and instructive phenomena that its result will afford.



Fig. 58.

Let the hydrometer-glass be thoroughly cleaned and dried; then select a piece of pewter, copper, or glass tube about two inches longer than the glass, and having a bore about the size of a goose-quill—even a sound hollow reed will answer the purpose—one end of the tube, whatever be its material, is to be placed at the pipe of a small glass or earthenware funnel, and secured there by a short piece of broad tape, imbued with solution of gutta percha, or by a strip of moistened bladder tied around with string, the object being to elongate the pipe of the funnel, that it may touch the bottom of the hydrometer glass, in which it is to be placed as represented in the accompanying engraving; the globes at the bottom of the glass will be described presently.

Place half a pint of rain-water in one finger-glass, and half a pint in another, add to the one as much powdered sulphate of zinc—sulphuric acid 40 + oxide of zinc 40,—and to the other as much powdered sulphate of copper, page 116, as the respective portions of water will dissolve, or, in more technical terms, obtain saturated solutions of the two substances which are called “salts,” although they differ from common salt in chemical composition and all properties excepting those of solidity and solubility in water.

By stirring these salts from time to time, with a separate piece of wood for each, in the course of a few hours the desired points of saturation will be gained, and indicated by a very considerable portion of each of the salts remaining undissolved; the solutions must then be separately strained through separate pieces of very fine muslin, drawn over separate sieves into separate basins, and then poured into separate glass bottles.

Mould three lumps of white-wax into the size of common playing-marbles; take one of these lumps, introduce therein

a few lead-shot, that will render it sufficiently heavy to sink through water, yet not sufficiently so to prevent it from floating upon the solution of sulphate of copper; this may be readily effected after a few trials.

Take another lump of wax, introduce therein a few more lead-shot that will render it sufficiently heavy to sink through the solution of sulphate of copper, yet not sufficiently so to prevent it from floating upon the solution of sulphate of zinc, then wash these ballasted lumps of wax in water—and also the hands, because the solutions are poisonous—and dry them with a cloth.

Cut a cork into the form of a ball, and cast or obtain a leaden bullet, of the same size as one of the lumps of wax, heat the bullet slightly, and rub a bit of wax upon it to form a thin coating, or rub it at once with black-lead.

Hold the hydrometer-glass in a sloping position, that the lumps of wax, the cork-ball, and the leaden bullet, when successively introduced at its mouth, may gently roll down its side to the bottom, then place it to stand upright upon the table, and introduce the funnel, with its lengthened neck, as shown in the preceding engraving.

Place about four fluid ounces of alcohol in a bottle containing about half a teaspoonful of bruised cochineal, cork the bottle, shake it frequently from time to time, until the alcohol become tinged of a deep crimson colour, or form what is technically called a tincture, page 133, to denote that it is a solution of colouring matter in alcohol or spirit of wine, instead of in water; thus pure brandy is colourless alcohol of a certain strength, but brown brandy is a tincture of the colouring matter of the wood of the cask in which it is kept, or of the colouring matter of burnt sugar, called caramel, that may be intentionally added to please the eye and palate of drinkers; such brown brandy might be substituted for the tincture of cochineal, but the latter is to be preferred.

Pour the tincture carefully from the remaining grains of

cochineal through a piece of fine muslin, stretched across a wine-strainer, the pipe of which is inserted in the mouth of the glass funnel with the elongated neck, down which the clear tincture will run into the hydrometer-glass, and float the cork ball; then remove the wine-strainer, and slowly pour into the funnel about an equal bulk of water—taking care that no air-bubbles become entangled with it, and proceed down the long tube to disturb the tincture—the plain lump of wax will now rise and float upon the surface of the water.

Then slowly and with the same precautions against the entanglement of air-bubbles, pour down a similar bulk of the solution of sulphate of copper; the lump of wax, containing the fewest lead-shot will rise and float upon its surface; proceed similarly with the solution of the sulphate of zinc, the lump of wax containing the most lead-shot will rise and float upon its surface, the leaden bullet alone will remain at the bottom of the glass, until, lastly, upon pouring down the tube a bulk of liquid mercury, the bullet will rise and float upon its surface as buoyantly as the cork floats upon the tincture, or the plain lump and the ballasted lumps of wax float upon the three other liquids.

Lift the funnel gently that the end of its elongated pipe may be exactly coincident with the surface of the solution of the sulphate of zinc, pause for two or three seconds, then lift it more gently, that the end of the pipe may be exactly coincident with the surface of the solution of the sulphate of copper; pause again for two or three seconds, then lift the funnel yet more gently, that the end of the pipe may be exactly coincident with the surface of the water; pause once more for two or three seconds, then lift it steadily through the tincture, and remove it entirely from the glass.

Having effected all these manipulations, the time and patience required for their performance will be rewarded by the display of the extraordinary phenomenon of five distinct liquids contained in one glass, in the exact order of

their specific gravities, four of them floating upon each other, all floating upon the lowest, and five solid masses floating upon the surfaces of five distinct liquids: a



Fig. 59.

casual observer, glancing at the arrangement, would naturally imagine it to consist of a glass cylinder, artificially banded at intervals with crimson, blue, and silver. The surface of the bullet is covered with wax or black-lead to prevent the lead from dissolving in the mercury, for which it has strong chemical affinity, and the great specific gravity of mercury is demonstrated, not only by the lead floating on it, but by its supporting the united weight of the

other four liquids. Several days will elapse before these will mingle, and when once mingled, no subsequent repose will cause their separation: the alcohol, the water, and the salts could only be obtained again by a refined chemical analysis.

The specific gravities of the earths, page 34, is greater than that of water, namely, alumina, 2·000; calcia, 2·300; magnesia, 2·300; silica, 2·660; and it is on account of the great specific gravity and insolubility of the earths, and of most of their natural compounds, that they chiefly subside with rapidity or precipitate from water when mechanically diffused throughout it by the force of inundations.

Earths and earthy compounds are not the heaviest solid forms in relation to water as a standard; the elementary metals that are best known surpass them all, thus the specific gravity of zinc, 7·000; tin, 7·300; iron, 7·780; copper, 8·890, silver, 10·470, lead, 11·350, gold, 19,250, platinum, 21·000; this last metal being the heaviest substance that has been discovered.

Some idea of the relative specific gravities of solids may be gained as follows: take the tare of a tin cup capable of

holding about one ounce of rain-water, then fill it with rain-water, ascertain exactly how many grains this water will weigh; the weight will afford a standard of comparison; pour away the water, dry the cup, remove all weights excepting those of the tare from the scale, fill the cup with fine sand, ascertain its weight, then proceed similarly with fine filings of zinc, iron, copper, tin, and lead; and it will be discovered, although the mass of each of these substances is nearly equal to the bulk of the water, the weight of each is different, and greatly surpasses it, and by calculating how many times the weight of the water is contained in each of their respective weights, an approach to their relative specific gravities will be obtained.

A more accurate proceeding is to obtain a solid cylinder of sandstone, and of each of the metals, exactly in size to the capacity of a cylindrical metal cup, then to ascertain the weight of water that it will hold, and remove the cup and all weights from the scales, and simply to weigh the cylinders in succession; lastly, to calculate how many times the weight of the water is contained in their respective weights; thus their specific gravities will directly appear, and will be nearly coincident with those stated to belong to the respective solid substances.

The specific gravity of gases and vapours is not ascertained in reference to the water standard as with liquids and solids, but with reference to an aerial standard, namely, the atmosphere itself, at a temperature of 62°, at the standard pressure of 15lbs. per square inch, or the barometer at 30 inches, page 23; the principle of the proceeding may be understood from the following description, but it is extremely difficult to put into practice, as gases and vapours are highly attenuated, and so subject to alteration of density by alternation of temperature. A glass globe is weighed, exhausted of its air, and its tare accurately taken; then admitted to fill the globe, and it is found to weigh 1000 parts; this volume of air is then withdrawn

from the globe, and its place supplied by an equal volume of oxygen. This volume will weigh 1111 parts; it is, therefore, heavier than air, or its specific gravity in relation to that of air is as one and one hundred and eleven thousandths to one thousand, or decimally thus, air 1·000; oxygen, 1·111; the oxygen is next withdrawn from the globe, and an equal volume of chlorine introduced; it will weigh 2470 parts; it is, therefore, more than twice the specific gravity of air, or decimally thus, air, 1·000; chlorine, 2·470.

The place of the chlorine is then supplied by carbonic acid; it will weigh 1500 parts; it is, therefore, exactly once and a half heavier than air, or decimally thus, air, 1·000; carbonic acid, 1·500.

Proceeding in this manner with nitrogen, its volume will not weigh even 1000 parts, but only 972 parts; it is, therefore, lighter than air, or decimally thus, air 1·000, nitrogen 0·972.

Lastly, if the globe be filled with hydrogen, its volume will not weigh even 972 parts, but only 69 parts; it is, therefore, lighter than either nitrogen or air; or decimally air 1·000, hydrogen 0·069. It is the lightest form of ponderable matter.

Returning to the examination of the curious phenomena attendant upon the transition of water from a liquid to a solid state, it is discovered that 1728 cubic inches of water expand in freezing and produce 1838·2978 cubic inches of ice, the specific gravity of 1728 cubic inches of which is 0·940, and it is in consequence of such expansion that solid ice can float upon liquid water.

The formation of ice is attended with most powerful expansion, several familiar examples of its effects will readily present themselves; we frequently find water in bottles not only densely frozen, but the bottles broken, or pipes for the conveyance of water split and rent asunder, if we reflect upon these occurrences for a moment, we must be convinced that a great force is brought into action during the congelation of water.

It is common to say that the bottles and pipes are broken by the frost; true, not however, by the mere cold of the frost, but by the expansion of the water in freezing, which these vessels and others of greater strength are unable to withstand; this can be proved by experiment. Boil half pint of water to expel the air that it contains; allow it to cool down to the temperature of the atmosphere; in the meantime select a thick glass bottle that will hold about four ounces, and a sound cork that will fit its neck accurately; pour some of the cold water into the bottle until it is quite full; then fold a thick cloth several times around; hold this firmly with one hand, thrust the cork into the neck of the bottle with the other, to the perfect exclusion of every bubble of air; secure the cork by tying it down with string, and carefully wipe away any water that may adhere to it, or to the neck of the bottle.

The use of the cloth is to prevent the hands from being wounded should the bottle break during the insertion of the cork; but suppose this has been done without accident, the cork and the neck must be dipped into hot cement, made by melting four parts of rosin with one part of wax in an iron pot, that the cork and the neck may be firmly cemented together.

When the cement is cold, place the bottle in a mixture of sand and salt, sufficient to cover it completely; this intense heat of itself will not cause any fracture of the glass, but in a few minutes a sharp crack will be heard, and it announces that the water has frozen, expanded, and burst the bottle, which will be evident upon removing it from the mixture.

Provide a tube of wrought iron, about an eighth of an inch thick, one inch in diameter, and four inches long, closed at one end, and having a female screw cut within its open end, and a male screw plug to fit this accurately—an iron pistol barrel, having its touchhole plugged, and its muzzle cut to receive a screw plug will answer for the experiment—fill the tube with boiled water, screw down the

plug as tightly as possible, then submit it to cold as last directed; the water in freezing will expand, and burst the tube. Many remarkable experiments have been made upon this expansive force of water in freezing; cast-iron bombshells, two inches thick and thirteen inches in diameter, were filled with water, and their apertures or fuse-holes firmly plugged with iron bolts; thus prepared they were exposed to the severe cold of a Canadian winter, between 4° and 19° below 0° , at the moment that the water froze, the iron plugs were violently thrust out, and the ice protruded; even in some instances the shells burst asunder, thus demonstrating the enormous interior pressure unto which they were subjected by the water in its assumption of the solid state. Beneficial effects are produced throughout the Creation from this expansive force of freezing water; thus, in spring, summer, and autumn, fertile soils by capillary attraction absorb and retain water for the support of their produce; during winter a portion of water at the surface of the soil freezes, and by its expansive force thrusts the individual particles asunder; but the ice then holds them apparently as solid clods of earth, until the warmth of spring returns; the icy cement then dissolves from the interstices, the particles of the soil loosen, and the clods crumble down, so minutely divided, as materially to lessen the labour of the husbandman in preparing the soil for seed.

The rounded, or weather-worn aspect, the degradation or decay of many rocks, more particularly those of limestone, sandstone, and slate, may be referred to the exertion of this singularly powerful agency of water; it is copiously absorbed into their fissures and pores by capillary attraction, and upon freezing therein expands, and thrusts their layers apart, and so hold them ice-bound until the return of spring, when thaw ensues, and they become detached, and fall: thus the original sharp or abrupt outlines of the rocks are gradually rounded or softened down.

During an extremely severe winter the sap of trees be-

comes frozen, and the expansion attendant upon the phenomenon rends them asunder with loud cracking or explosion; we also observe illustrations of this expansion taking place upon a minor scale by the flag-stones of pavements suddenly starting from a level position, and the mortar of walls peeling away in flakes; careful masons and bricklayers being well aware of this fact, never undertake work requiring cement or mortar during the continuance of frost, for in the course of a few hours it would be destroyed by the expansion of the water in freezing.

When careful masons and bricklayers anticipate frost, they invariably cover the new work with thick layers of straw or matting, which having extremely bad conducting power, will prevent the water in the cement or mortar from freezing, and producing injury by its expansion.

It is a very common domestic practice during winter to surround water-pipes with thick hay or straw bands, or to cover them with litter from a stable, and thus, by the non-conducting power of such organic matters, prevent the freezing of the water and the rupture of the pipes that might otherwise ensue.

In a service-pipe a few feet beneath the surface of the earth, water will seldom freeze unless the cold be extremely severe, as the earth is so bad a conductor; but the part of the pipe which emerges from underground into the open air—as in passing from the street main across a kitchen sea—being thus exposed, the metal by its good conducting power will soon chill the water and cause its own rupture, hence such part of the service-pipe requires to be bound round with hay, straw, or other non-conducting material to prevent freezing; or if the tap at the extremity of the pipe to the house be left partly open, the water instead of remaining stagnant and likely to be frozen, will constantly flow and in a great measure oppose the cooling power of the external atmosphere.

In performing the experiment regarding the congelation

of water page 306, the thin flask does not generally break when ice forms, because the neck being open admits of the expansion; if a considerable portion of water freeze in this, and particularly if it become narrow towards the mouth, the ice will act as a solid plug to the water beneath, and will oppose its expansion, therefore it will be exerted around the interior of the flask, which will soon break; hence the necessity of applying the freezing mixture more around the bulb than the neck.

In the experiment with the cryophorus page 179, the instrument should be removed from the freezing mixture the moment after the ice has formed upon the surface of the water in the upper bulb; for if it be not perfectly spherical it may break by the expansion induced by the congelation of the remaining water.

During the natural cold of winter, when a glass carafe containing water breaks by frost, it will be generally found that it was nearly full of water, the freezing of that in the neck having acted as a barrier against the subsequent expansion of congelation of that in the bulb; but it sometimes happens that the carafe escapes fracture because the cold air—like the freezing mixture—simultaneously enveloping it on all sides, quickly reduces the whole temperature of the water to the freezing point, and the open mouth admits of the total expansion, or, in other words, the ice will rise towards it, in preference to exerting pressure upon the interior of the bulb; again, if the carafe be only half full of water, its fracture will seldom ensue, as there is sufficient room for its expansion in freezing.

Ice has most extraordinary antiseptic power, as the following remarkable natural example will prove;—in the year 1803 at Yakoust, on the banks of the river Lena, in Siberia, the body of a mammoth slowly appeared from a mountain of ice in which it had been entombed and preserved from decay, in all probability from the time of the Deluge; the animal was sixteen feet in length, nine feet in height, and

the flesh was in such excellent preservation, that not only did the bears and the wolves devour it with eagerness, but the inhabitants of the district actually cut it up as food for their dogs. Knowledge of this antiseptic power of ice, is of great importance to us for the artificial preservation of animal food, for if it be packed in ice it will not undergo decomposition, because the liquid water that animal food naturally contains as a leading proximate constituent, is rendered solid by the low temperature; and in such state, although still consisting of oxygen and hydrogen,—it is capable of promoting those changes or new arrangements of the ultimate elements of organic matter called putrefactive changes, as it is capable of doing when in its ordinary liquid form.

Such frozen provision, if very slowly thawed, and then immediately submitted to culinary operations, become wholesome food; otherwise it rapidly putrefies as it would in a recent state.

In Russia, during the winter, large and transparent blocks of ice are quarried from the surface of frozen rivers, and stored in cellars for the preservation of food; oxen and sheep are slaughtered, dismembered, and allowed to freeze; the meats are afterwards packed in casks, and sent to market: although so hard as to require an axe to break them, the flesh softens by the thawing of the ice when immersed in cold water and is then fit for cooking.

Large quantities of salmon are shipped from Scotland packed in boxes with ice; indeed so important are its antiseptic powers that of late years it has been imported from the shores of the lakes of North America; the chief employment of it is by fish-merchants, for the preservation of their stock during the heat of summer, because the organic fibre of fish is exceedingly prone to putrefy, by a very moderate elevation of natural temperature.

Confectioners likewise employ large quantities of ice, in obtaining a low temperature for making ice-creams, water-

ices, and other cooling luxuries of the table, which are so grateful during the heat of summer; and the collection of ice for all the above purposes affords employment for many poor, yet industrious persons during the chill season of winter.

Accordingly, upon the first intelligence that ponds are frozen over in the vicinity of London, those whose avocations lead them to be stirring at day break, meet parties of men and boys proceeding with crowbars, forks, rakes, poles, ropes, baskets, and nets, in waggons, vans, and carts of every denomination, drawn by horses and asses of all grades in search of ice; a direct luxury to the rich, an indirect treasure to the poor, as by its collection, although a chilling, comfortless, and hazardous task, they earn a scanty pittance, which providently expended upon the necessaries of life, will enable them to keep distress and famine from their abodes, for a short time at least, during the winter season that brings no festivity within their walls.

The ice thus collected is carted to the shops of fishmongers, confectioners, and tavern-keepers, and received in their ice-houses; the construction of these receptacles for the preservation of ice throughout the four seasons, depends upon scientific principles illustrative of the bad conducting power of earth and air, and therefore demand a general description in this inquiry.



Fig. 60.

The sole object is to prevent the accession of heat to the ice, and therefore an ice-house or an ice-well is usually formed at a considerable depth in the earth, especially in the metropolis, where the surface is of such value.

A cavity is dug in the earth, in the shape of an inverted cone, and then built around internally with thick brick-

work like a well, as represented in the accompanying sectional engraving.

At the bottom of this cone of brick-work, a cart-wheel is laid flat, to serve as a grating, and immediately beneath this is a small brick drain sloping gradually towards the larger street drain, or the main sewer.

About the middle of the small drain a small tank is placed, and a large paving tile, or slab of stone, descends from the upper part of the course of brick-work of the small drain, to within a few inches of the bottom of the small tank, and this is half full of water.

The upper part of the inverted cone is covered with a dome of brick-work, in the centre of which is an aperture, of any size most suited to the whole structure; and the horizontal part represented in the engraving, which proceeds from the white space on the left hand, denotes a brick-work passage, having two or three doors by which access can be gained to the interior of the ice-well; this is charged with ice in the following manner:—

The aperture in the dome is opened, as also the doors of the passage, a truss of clean straw is unbound and thrown down evenly upon the cart-wheel; the cart-loads of ice are then emptied on the street-pavement, and the ice is rapidly broken by clubs and mallets into fragments small enough to pass through the aperture in the dome.

These fragments are quickly shovelled down, and when sufficient quantity of them has fallen, one or two men, according to the size of the well, descend, and beat the ice firmly together with heavy wooden rammers; more ice is then shovelled down, and beaten, and so on until the well is perfectly and compactly filled; the workmen then pass it through the horizontal passage.

The aperture in the dome is then completely closed by a slab of stone, which rests upon a ledge formed for its reception; the shaft above this is several feet in perpendicular extent, and its top or mouth is accurately covered with

another slab of stone, level with the street pavement ; thus a considerable column of air is closely imprisoned and rendered stagnant between the upper and the lower slab, and this air, by its non-conducting power, cuts off the access of heat from the pavement to the dome of the ice-well.

The door in the brick-work of the ice-well is then closed, and the space between it and the next door in the horizontal passage is closely filled in with dry straw ; this second door is then closed, and the space between it and the third door similarly filled, and so on until all are closed ; the air and the straw thus confined, cut off the access of heat from the area of the house to the ice in this direction, and the operation is finished.

Notwithstanding all these precautions a portion of the ice will thaw, but the resulting water filters through the remaining ice to the straw, and from it between the spokes of the wheel into the small drain ; and as it accumulates in the small tank, it overflows and passes into the sewer, at the same time the vertical slab of stone or paving-tile forms an effectual barrier against the admission of warm air from the street drain or main sewer, so that by all these contrivances depending upon the bad conducting power of the earth, the brick-work, the straw, and the air, the ice is prevented from obtaining much heat from the external atmosphere, and the chief mass of it remains at 32 throughout the greatest temperature of summer.

A considerable thawing of the ice takes place when the doors are opened for withdrawing such portions as may be required for use ; on this account, and also on that of the trouble required for the removal of the straw barriers, and shutting one door before another is opened, the proprietors of these ice-wells never have them entered more frequently than may be absolutely necessary for the purposes of their trades.

As in a former experiment, page 246, a heating focus was

obtained by allowing the solar rays to enter and emerge from liquid water, so can a like result be obtained with solid water, or in other terms a burning lens can be formed of ice.

Obtain a hemispherical mould of tin or zinc plate, in fact a bowl about one foot in diameter, place its hemispherical part to stand upon the rim of a large saucepan about half full of water, boiling on a fire in the usual manner, select a block of the most transparent and perfect ice that can be obtained—American ice is to be preferred—considerably larger than the bowl, and then with a hammer chip away the solid angles of the block until it will just enter the bowl.

Of course the thawing of the ice will immediately commence, the resulting water must be poured away from time to time, and the thawing allowed to proceed until the remaining ice has completely settled into, and taken the hemispherical shape of the bowl, which must then be moved from the rim of the saucepan, and placed upon a table.

Take a shallow flat-bottomed tin or zinc pan about one foot in diameter—in fact a cake tin—place its lower part to stand upon the rim of the saucepan containing the boiling water, then upon the table place two pieces of broad tape about two feet long, the one crossing the middle of the other, remove the ice from the bowl, and holding its rounded face upwards, place its other on the middle of the crossed tapes, gather their ends and unite them in a knot upon the upper and rounded surface of the ice, then lift it by the knot into the cake tin, and let the thawing proceed until the lower surface of the ice become perfectly flat; then lift it out, and place it in the middle of a large square of muslin or baize, untie and remove the tapes, and fold the muslin or baize closely around the newly formed plano-convex lens of ice, that it may be prevented from thawing

any more on account of the bad-conducting power of the woollen envelope.

Put on a pair of thick woollen gloves, carry the ice-lens into the open air, place a piece of amadou tinder upon any convenient support, then remove the ice-lens from its covering, hold its plane surface to the rays of the sun, move it about that its convex surface may be within a few inches of the tinder, and at length find its focus; adjust the distance that it may fairly fall upon, and kindle the tinder, and thus prove that the solar rays have lost no heat in passing through the transparent ice.

Even in the Arctic regions the rays of the sun have been thus collected by a lens of ice into a focus sufficiently powerful to inflame gunpowder; in this country ice can always be obtained from ice-houses at all seasons, therefore the experiment can be made during spring, summer, autumn, or winter, taking care to wipe away the drop of water that may result from the partial thawing of the ice by the heat of the surrounding air, and hang from the centre of the convex surface of the lens, when its proper focal distance is obtained.

In extremely cold weather, fish-ponds are so firmly frozen over, that the sheet of ice forms a perfect barrier against the access of the atmosphere to the yet liquid water beneath, and fishes would eventually perish, not by cold, but by the mephitic results of their own respiration, page 238, for solar light is feeble in the wintry atmosphere, and is rendered more feeble by passing through the ice; the aquatic plants are not fully stimulated to exert their miraculous decomposing power upon the carbonic acid: it therefore would prove fatal.

We accordingly break holes through the ice, and then remark how eagerly the fishes swim towards these, and directly breathe the newly admitted air, exactly as we ourselves, after long confinement in a close room, the air of

fish has been gradually vitiated by our respiration, gladly advance to the window, open the sash, and thus admit fresh air to relieve our faintness.

These holes in the ice require to be kept open from day to day during the continuance of the frost, that the mephitic effluvia of respiration may partly escape, or chiefly that the fish may come to the surface and breathe; drawn thither by necessity, they eagerly seize baits that may be introduced by fishermen, who being aware of the fact, turn it to their own account.

In the case of very deep and extensive ponds, naturally formed, we may generally, if not invariably remark, that they are not frozen over in one continuous sheet of ice, of uniform thickness and opacity; but in many parts circular openings, several feet in diameter, consisting of extremely thin and transparent ice, are distinctly visible; and in the centre, even large circles of perfectly liquid water ripple in under blast: these phenomena announce the power and wisdom of Providence, and the miraculous provision which is made for the welfare of the inhabitants of the waters. Although the cooling of the entire bulk of the water of a pond might have proceeded by the intensity of the atmospheric cold to the degree required for the formation of a uniform sheet of ice, it must be remembered that the ice thus incapable of receiving water from the clouds is yet capable of receiving water from the earth below; and as water is constantly gushing through its bed, the temperature of such water is many degrees greater than that of the pond; it therefore ascends, and coming into contact with the lower surface of the ice, commences its work of melting; those spots immediately above the spring in the earth from whence it ascended.

As the spots become thinner and thinner, and so frail that they can easily burst through them, and gain not only fresh air, but a more genial temperature than that of the main bulk of the surrounding water; or if the crea-

tures do not break the fragile ice, the winter wind will often do so, and thus free them from imprisonment; or even if neither force thus operate, the still ascending warm water from the earth, will dissolve the ice within prescribed limits, and thus free the creatures from the oppression under which they temporarily suffered.

But this is not the whole or sole beneficent provision that the Creator has made for the welfare of the inhabitants of the waters. He, for the fulfilment of a recondite purpose, may ordain the cold of winter to be so intense and so protracted, as to congeal the entire surface of the water into one sheet of ice of uniform thickness, and thus prevent the access of the atmosphere to the yet liquid water beneath; in such case He then ordains the earth to cease the supply of water from its springs, and to exert its own property of attracting or draining away a portion of the water from beneath the ice, which then deprived of support, gradually yields to the pressure of the superincumbent atmosphere, bends slowly to the utmost verge of its own elasticity, at last it suddenly cracks, and freely admits the air.

The important fact to be borne in mind regarding the congelation of water, is this, when ice has formed, it matters not how much below 32° , the temperature of the winter may descend, the liquid water shielded by the ice, will maintain the immutable temperature of 40° ; indeed when the air is at, or below 0° , if we break a hole through the ice, the water at 40° sends forth warm vapour which the cold air immediately condenses into minute crystals appearing like white smoke.

An appearance of this kind is often seen hovering over marshes and brooks, and most remarkably so over the Greenland seas; it is there known as "frost-smoke," and in all cases is formed by the sudden congelation of aqueous vapour; the phenomenon ceases when the surface of the water and the incumbent air become cooled to an equal degree.

The aqueous vapour exhaled from our lungs is perfectly visible on a hot summer day, because the air is too warm for its condensation; if we breathe into a cold glass, the aqueous vapour condenses and dims its surface; and it becomes solidified into frost on a cold winter day, because the air is sufficiently reduced in temperature to cause its condensation and congelation.

Occasionally in Lapland, when the door of an apartment in which persons are assembled, is suddenly opened, and a quantity of cold air admitted, the aqueous vapour exhaled by respiration is instantly frozen into flakes.

On the early days of winter, and at various times during its continuance when the land may be soft, the deep foot-prints of the husbandman, the deeper hoof-marks of cattle, the deepest ruts of wheels, all become filled with the water of the next ensuing shower, this glistens in the pale sunbeams like spots, patches, and threads of silver, and, by the strong contrast of the dark soil, forms a pleasing embellishment of the wintry landscape. If the shower be succeeded by a sharp frost, then all these little pools and rivulets are frozen, and being thus assimilated in whiteness with the surrounding heavy rime, they no longer strike the eye with their former bright silvery contrast, but will be lost to other beauties if he stoop to the examination of things so minute; and this he must do, if he be a lover of wisdom.

In many of these foot-prints, hoof-marks, and wheel-ruts the ice will be in the form of beautiful crystals, crossing each other at angles of 60° and 120° , thus forming an intricate work, through the interstices of which the dark soil is visible; within others again, the ice will be in the form of a perfect crystalline film; if either form be broken away,

the slightest trace of liquid water can be discovered, but the surfaces are all perfectly dry, and yet we must feel that the delicate crystals, or the fragile film, cannot support the whole of the water in a solid form.

The water in all the cavities was cooled by the frosty air, though in some, with more slowness than in others; accordingly in the first case, crystals of ice formed at the sides, gradually accreted and individually shot across the water, and would have entirely covered its surface, had not another agent been simultaneously active, namely, the capillary attraction of the soil, which drew away or absorbed the water with a rapidity superior to that of the cooling influence of the air; and thus the slightest subsidence of the water from the nascent or newly-formed crystals, of course prevented their farther increase; this capillary attraction ultimately absorbed the whole of the water from the cavities, leaving a crystalline net-work of ice.

In the second case, crystals of ice formed with rapidity superior to the power of capillary attraction, and thus accreted into one entire sheet; but this, however thin, prevented cold from penetrating to the water beneath, so that capillary attraction alone remained silently though certainly active, and at length drew away the whole of this liquid water, leaving the film of ice suspended in the cavities at the point of its formation.

These beautiful phenomena, for such they are, although of such common occurrence, are chiefly displayed upon light calcareous soils, which are not very retentive of excess of water, whilst in the foot-prints, hoof-marks, and wheel-ruts in compact clayey soils which are very retentive, the crystalline net-work seldom occurs, but only the icy film, and if it be broken, water appears beneath, as no channel for its rapid escape was afforded by capillary attraction.

Stagnant water, or water only subject to comparatively slight disturbance, universally presents the phenomenon of the formation of ice upon its surface—as now fully described—but in rapid and impetuous streams, the formation of ice when it occurs, is often exactly the reverse, and it is popularly called “ground ice.”

During our inquiry regarding the chemical phenomena of spring, summer, autumn, and part of winter, we have learned several important facts, viz., that the temperature of the earth in this season is greater than that of the air; that radiant heat will pass through transparent media without increasing their temperature; that a cloudless sky is essential for radiation to ensue; and that it will ensue with the greatest rapidity from rough surfaces. Chemistry applies all these facts to aid in the explanation of the phenomenon of the formation of ground ice.

The beds of the rivers and streams already mentioned, consist of rugged rocks and stones; these contain a certain degree of heat, and part with it, not by conduction, not by convection, but by direct radiation through the water to the cloudless sky; thus reduced in temperature, they quickly cool the water in their immediate contact, and suddenly cause it to freeze in films upon their surfaces, these films remain whilst radiation and the cloudless sky continue, but radiation ceases when clouds appear.

The solid surfaces then communicate sensible heat to the water, or the clouds may radiate heat through the water to the water; which, unlike surface ice, is not smooth and glassy, but rough and porous; therefore capable of absorbing radiant heat in a sufficient degree to cause partial thawing to take place, and from the solid rocks and stones, the detachment of fragments of the ice; these accordingly rise to the surface of the water, and oppose all further radiation from below; by actual contact, then cool the water until a perfect crust of ice be formed as usual.

The formation of ground ice only ensues naturally upon rugged rocks and stones which form the beds of rapid rivers; when other solid objects, such as branches and more especially, are placed beneath the water, the formation of the ice is copiously induced upon them; and at last, combined with the clearness of the sky, to favour

rapid radiation, furnishes a clue to the explanation of the phenomenon.

Let us now turn to the contemplation and investigation of another beautiful attribute of winter, that also displays the wisdom and beneficence of the Almighty.

"Great things doeth He which we cannot comprehend; for He saith to the snow, be thou on the earth."

"By His commandment He maketh the snow to fall apace; as birds flying He scattereth the snow: and the falling down thereof is as the lighting of grasshoppers: the eye marvelleth at the beauty of the whiteness thereof; and the heart is astonished at the raining of it."

Snow thus eloquently and impressively described, very probably depends for its formation upon the gradual congelation of aqueous vapour in clouds amid the higher and colder regions of the air, where its capacity for heat is increased by expansion; the water thus becoming solidified loses the support of the air, and the newly formed crystalline snow-flakes, in obeying the attraction of gravitation, descend, and softly cover the earth with a mantle of spotless white.

This perfectly conceals the lowly remnants of vegetation from our sight, but we have reason to be grateful for its presence, snow, like ice, being an extremely bad conductor; it therefore protects seeds, bulbs, and roots from the chilling winds that sweep over its surface, as effectually as the shield of ice protects the beings of the wave beneath: vegetable productions are thus preserved from intense cold by a mantle of snow, as perfectly as they would be by a fleece of wool.

Thus in the beautiful and impressive language of Scripture—"He giveth snow like wool."

The passage refers to the similarity between flakes of snow and fleeces of wool, in whiteness and lightness, and in power of preserving warmth around the bodies which they shield and clothe.

Snow is a great preservative against the effects of cold; wheat will continue growing beneath deep snow, whilst every blade would be killed by hard frost without snow; beneath the surface, the temperature of snow is very little colder than 32° , whilst the air above is frequently 20° or 15° below that point.

If a piece of ground be left covered with snow, and a contiguous piece of ground be swept clean, after a day or two, upon digging both, it will be found that the frost has penetrated very considerably below the surface of the piece cleared from snow; indeed it is recorded, in illustration of the protecting power of snow, that in Holland during the cold winter of 1776, the surface of the earth was frozen to a depth of twenty-one inches on a spot of garden ground kept free from snow, but only to nine inches on an adjacent spot covered with four inches of snow.

In the northern regions, snow lying on the ground twelve inches deep during winter, preserves the vegetables which are destined to adorn summer, although the cold of the atmosphere may be many degrees below zero.

The reflection of solar heat by white, and its absorption by black surfaces, is well illustrated during the winter, by snow remaining for many hours without thawing in the shade, whilst if its surface be lightly covered with black cloth, the thawing will immediately commence.

The nine pieces of cloth employed in a former experiment during summer, page 208, be spread upon the surface of snow when the sun shines, their different absorptive powers, as regards solar heat, will be illustrated by the piece and the darkest coloured pieces absorbing more heat, and therefore thawing more snow, and consequently sinking deeper below its surface than the white piece and the light coloured pieces.

Esquimaux have learnt to convert snow into building blocks, by which means they can raise a dwelling for families in a few hours; a dwelling which, from the

purity of the material of which it is composed, the elegance of its construction, and the translucency of its walls, give it an appearance superior to that of a marble building.

Having selected a spot where the snow is sufficiently compact, the Esquimaux commence by tracing out a circle of from eight to fifteen feet in diameter, proportioned to the number of occupants the hut is to contain; they then prepare a number of oblong slabs of snow, of six or seven inches thick, and about two feet in length, which are tenacious enough to admit of being moved without breaking, or even losing the sharpness of their angles.

These slabs, which have a slight degree of curvature corresponding with the circular foundation, are piled upon each other exactly like courses of hewn stone, and care is taken to make them fit closely to each other by running a knife adroitly along the under part and sides, and to cut them so as to give the wall a slight inclination inwards; tier after tier is thus laid on by one man standing within the wall, who is supplied with material by one or more assistants from without; but for the better convenience of transmitting this supply to the workman, when the wall has attained a height of five or six feet, a hole is cut on the south side close to the ground.

Thus they continue labouring, until they bring the sides nearly to meet in a perfect and well-constructed dome, sometimes nine or ten feet high in the centre; and this they take particular care in finishing by fitting the last, or key-slab, very nicely in the centre, dropping it into its place from the outside, though it is still done by the man within; the people outside are in the meantime occupied in throwing up snow with the snow-shovel, and inserting little wedges of snow where holes have been accidentally left.

The builder next proceeds to let himself out, by enlarging the hole on the south side into the form of a pointed arch, intended as a door-way, three feet high, and two feet and a half wide at the bottom, communicating with which he

constructs two passages, each from ten to twelve feet long, and from four to five feet in height, the lowest being that next to the snow-house; the roofs of these passages are sometimes arched, but more generally made flat by slabs laid on horizontally; in first digging the snow for building the hut, the workmen take it principally from the part where the passages are to be made, which purposely brings the floor of the latter considerably lower than that of the house, but in no part do they dig till the bare ground appears.

The work just described completes the walls of a house or hut, if a single apartment only be required; if several families are to reside under one roof, the passages are made common to all, and the first apartment in that case made smaller, forms a kind of ante-chamber, from which the entrance is through an arched door-way, five feet high, into the inhabited apartments; there are generally three of these, and then the whole building, with its adjacent passages, forms a tolerably regular cross.

For the admission of light into the huts, a round hole is made on one side of the roof of each apartment, and a circular cake of fresh-water ice, three or four inches thick, and about a foot in diameter, let into it; the light is soft and pleasant, like that transmitted through ground-glass, and quite sufficient for every purpose; if fresh-water ice be within reach, melted snow is poured into a vessel, and is frozen into a transparent plate.

When these edifices become surrounded by drifted snow, they can only be recognized as human habitations by the openings, and when these are concealed no persons would suspect that human beings were beneath the snowy mounds. A bank of snow, two feet six inches high, is then raised around the interior of each apartment, except on the side of the door; this bank, which is neatly squared, is to protect the beds and the fire-place, the former occupying the sides, and the latter the end opposite the door; the

passage left open up to the fire-place is between three and four feet wide.

The beds are arranged by covering the snow with a quantity of small stones, over which are laid paddles, tent-poles, and some blades of whalebone; above these are placed a number of little pieces of net-work, made of thin slips of whalebone, and lastly, a quantity of twigs of birch; so that deer-skins, which are very numerous, can then be spread, without risk of touching the snow; such a bed is capable of affording comfort, although the rigour of the climate may be severe.

With the lamps lighted, and the hut full of people and dogs, a thermometer placed on the net over the fire indicates a temperature of 38° , when removed two or three feet from this situation it falls to 32° , and placed close to the wall stands at 28° ; the temperature of the open air at the same time being 25° below 0.

A greater degree of warmth than this produces extreme inconvenience by the dropping from the roofs; this they endeavour to obviate by applying a little piece of snow to the place from whence the drop proceeds, and this adhering, is in a short time an effectual remedy; but for several weeks in the spring, when the weather is too warm for these edifices, and still too cold for tents, the inhabitants suffer much on this account.

The interior of these habitations is rendered more beautiful when they are situated on the ice, which, being cleared of the snow, presents a flooring of that splendid blue which is perhaps one of the richest colours in Nature.

As the spring advances, the snow walls melt and freeze alternately, forming innumerable icicles, which reflect the light like radiant diamonds; although this is very beautiful, it is a source of great trouble to the poor inhabitants whose lungs become affected from repeated colds and draughts, for this reason: although the houses are formed of snow, coolness is the object always kept in view, and from the

inexhaustible building materials always at hand, but little time and labour is required to effect any alterations or additions that may be requisite to effect the purpose.

Equal in beauty to the snow-houses are those constructed of fresh-water ice; when this material is employed, it is collected in large transparent slabs, which are arranged in an octagonal form, and plastered together with snow; the roofs of some are formed of walrus skins, and others have the regular dome-tops of snow; these dwellings are so transparent that even at some paces distant it is possible to distinguish those who stand within them, yet they are so completely air-tight as to be perfectly warm; a passage of the same pure material forms the entry to the hut.

The phenomenon of red snow, which is occasionally presented in the Arctic regions, is probably referrible to the growth on the surface of white snow, of a lichen called the *palmella nivalis*; it contains a peculiar resinous principle, of an orange-red colour, of which the oxide of iron forms a constituent; the colouring matter penetrates to various depths into the snow, and when microscopically examined it appears in the form of globules, varying from one thousandth to a three thousandth part of an inch in diameter.

The beautiful crystalline forms of snow-flakes may be readily determined by catching them on a piece of black cloth, or on the top of a black hat, and immediately examining them with a powerful magnifier; they will be found to present regular figures—as shown in the engraving—which may be regarded as the frame-works or skeletons of the solid six-



Fig. 61.

sided prisms into which water is more compactly frozen to constitute hail-stones.

Throughout the four seasons the Almighty likewise, "By His great power He maketh the clouds firm, and the hail-stones are broken small."

So far as the physical cause of hail can be discovered, it appears to depend upon the extremely sudden congelation of rain-drops in falling through a stratum of cold air; the hail-stones thus formed are more dense and compact than snow-flakes from vesicular vapour, page 194, they more promptly cleave the air, and strike the earth with great violence.

From some mysterious physical cause, hail is more frequent than snow in spring, summer, and autumn, and is dreaded by the husbandman on account of the devastation that it produces upon growing crops; but these heavy showers of hail and rain during thunder-storms are instrumental in restoring the electrical equilibrium between the atmosphere and the earth, after its disturbance by the long continued heat of the season, as mentioned, page 190; when considering the thunder-storm, thus we have reason to be grateful to Providence for "Fire, and hail, snow and vapours, stormy wind fulfilling His word."

In winter again, "The hoar-frost, also as salt, He poureth upon the earth, and being congealed, it lieth on the top of sharp stakes."

This beautiful phenomenon appears to result from the condensation of vesicular vapour into exceedingly minute drops, and the slow congelation of these into crystalline particles more attenuated than those of snow-flakes; these particles of hoar-frost falling through the air, are received by leafless branches, evergreens, blades of grass, roofs, fences, stakes, and other natural and artificial solid objects, which act as points of support or nuclei; around such they accrete like crystals of salt, and charm the eye with the purity of their beauty; but in our temperate climate they only glitter for a brief time in the wintry beams of the sun,

then liquefy and vaporize by the heat, and lastly dissolve again in the air.

A crystalline resemblance to that of hoar-frost upon the branches and leaves of evergreens, may be artificially effected by the following arrangement: procure a few drams of crystalline benzoic acid: it is obtained from gum-benzoin, and even this will answer the purpose of the experiment to some extent, if the pure acid cannot be procured.

Clean the glass-shade and plate that were employed in a former experiment, page 151, by washing them well with water, and carefully drying them with a cloth; place them so warm at some distance from a fire, turn the glass-shade from time to time, that it may warm equally, place a shallow pan, about two inches in diameter, to become hot, upon the top bar of the fire-grate.

In the mean time select a branch of *arbor vitæ*, that will easily pass into the glass-shade, mould a small lump of clay, in which thrust the lower end of the branch to stand upright, drop a small pinch of the benzoic acid into the pan; if a white vapour quickly arise, the pan is sufficiently heated, if the white vapour do not quickly arise, the pan must remain upon the bar until the volatilization of other portion of the acid will quickly ensue.

Remove the glass-shade and plate to a table; heat three or four copper penny-pieces red-hot, take them from the fire with the tongs, set them one upon the other nearly in the middle of the plate, then set the heated pan upon the red-hot coins; place the lump of clay, with the branch of the *arbor vitæ*, to stand in the plate near them, quickly fill the pan with the benzoic acid, and immediately cover the whole arrangement with the glass-shade.

The benzoic acid will volatilize, and its vapour coming in contact with the branch, will be chilled by it, and condense upon it in the form of beautiful and delicate snow.



Fig. 62.

white crystals, very closely resembling hoar-frost; the accompanying engraving shows the arrangement for the performance of this extremely interesting and instructive experiment.

It illustrates a process known in Chemistry as that of sublimation—a technical term derived from the Latin *sublimis*, *high* or *exalted*—it may be defined as the exaltation of a solid body into vapour by heat; and the subsequent precipitation of that vapour into a solid form by cold, but the

change is merely physical: in the case before us the acid merely changes from solid to vapour, and then again becomes solid, it undergoes no chemical change of composition—unless heated very high and then it burns—thus if gum benzoin were employed, the pure volatile acid would sublime from it and condense on the branch, leaving any fixed matters of the gum in the tin pan, and by such sublimation the pure acid—which answers best for our experiment—was originally obtained in a chemical laboratory.

The process of sublimation does not frequently occur as a natural phenomenon, as very few solid substances, unless artificially extracted from natural sources, are volatile to any extent by the ordinary changes of temperature during the four seasons: but in the immediate vicinity of those extraordinary mountains called volcanoes, the process of sublimation proceeds upon a vast scale with regard to sulphur, it being probably raised into vapour by the heat of subterranean fire, and when the vapour penetrates through the cracks and fissures of the volcanic soil to the surface, it thereon condenses into solid, transparent, yellow crystals, or solid opaque amorphous masses. These collected by the

industry of man, constitute the chief supplies of native sulphur for the use of Chemistry and the chemical arts.

Returning to the experiment from whence these remarks originated; upon removing the branch incrustated with crystals resembling hoar-frost—though not produced upon the same principle as that phenomenon—it cannot be kept exposed to the air, as the acid will gradually volatilize, but it may be preserved for a considerable time, if covered with a glass-shade, in a cold room, and if the crystals become accidentally shaken from their fragile hold, they may be collected and sublimed again upon the branch as at first, or upon a branch of green holly with scarlet berries, which will present even a more beautiful appearance, and form a philosophical decoration for a room during the season of Christmas.

If the experiment be performed in early spring, and the acid limed around, and condensed upon a bunch of almond blossoms, an appearance will be produced analogous to the beautiful phenomenon which actually ensued in the western suburbs of London on the 20th of March, 1846, when the blossoms of almond trees were suddenly covered with fine and delicate crystalline flakes of snow; at the same time the vegetation generally was extremely forward, many especially elms and hawthorns, had put forth small green leaves, thereby exposing considerable surface for the reception of the snow-flakes, and by the contrast of the colour of their lower surfaces, caused the whole scene of the landscape to be far more striking than it is in England, during mid-winter, with the few snow-covered evergreen and leafless branches of vegetation.

The chemist discovers that substances capable of assuming crystalline form, will generally adhere to rough or porous surfaces in preference to such as are polished and compact; accordingly introduces sticks and strings into various vessels of salts, to act as nuclei for the accretion of their crystals, which will cluster upon them in preference to the

smooth sides of the vessels employed for containing the solutions; the most familiar examples of this kind are presented by crystals of verdigris—acetate of copper—on sticks, and crystals of sugar-candy upon strings.

During the last experiment, the crystals of benzoic acid were deposited more abundantly upon the rough leaves of the branch than upon the smooth surface of the glass.

Many natural examples of these facts are presented, thus the crystals of water constituting hoar-frost, are found more plentifully deposited upon leafless branches and grass-plats, than upon stone pavements and gravel-walks, indeed, surfaces like the latter may be perfectly free from hoar-frost, whilst a few withered leaves, straws, or feathers, lying upon them, will be abundantly incrustated with beautiful crystals.

During the congelation of water, the crystals of ice will form first upon the stones, grass, weeds, or moss at the border of a pond or stream, and then gradually proceed across the surface.

The delicate frost work resembling trees and landscapes,



Fig. 63.

which forms during winter upon the interior surfaces of window-panes, results from the congelation of the vapour of the water contained in the air of the apartment, and the same appearance displays itself inside the glasses of a close carriage, from the congelation of the moisture exhaled by the lungs of its occupants.

The appearance of hoar-frost upon a window-pane may be artificially imitated by dissolving an ounce of Epsom salts—sulphate of magnesia—in about a wine-glassful of boiling water, and then with a sponge spreading the resulting solution quickly and evenly over the surface of a warm pane of glass; as it cools, beautiful crystals will incrust the

surface in a variety of arborescent or tree-like forms; and by this simple proceeding window-panes are now very commonly "frosted," as it is termed, to avoid the more expensive method of rendering them opaque by grinding.

Occasionally during winter in London, the flag-stones of the foot-pavements exhibit, at day-break, the most splendid examples of this crystalline form of water, the crystals being arranged, interlaced, and interwoven in an endless variety of the most delicate and intricate figures that it is possible for the imagination to conceive, by a very slight thaw occurring in the night, and the films of water suddenly congelating by a sharp frost setting in at day-break.

If the conflagration of a building happen during a very severe frost, the water thrown on by the engines to quench the flames, is often frozen as it dashes and trickles down the walls, and forms brilliant icicles, pendent from the parapet, portico, balconies, and window frames.

The natural formation of icicles depends upon the congelation of successive drops, or slender streams of water, and they sometimes accumulate so greatly upon trees that the branches break under the weight, and thus material damage to future growth ensues.

Leaving for a time the examination of the effect of natural and artificial diminution of temperature upon water, let us investigate the phenomena presented by this wonderful liquid when subjected to artificial increase of temperature, as in the familiar process of boiling.

Why should the heat be invariably applied beneath the vessel containing the water, and not upon the surface of the water? The answer to this apparently simple question involves great refinements of chemical science.

Water is a non-conductor of heat; if heat be directly applied to its surface, the portions of water constituting such surface will by the mere heat of contact become elevated to the boiling point, and this boiling film being specifically lighter than the colder portions of water be-

neath will float upon them, whilst they cannot derive heat from it on account of their non-conducting power.

This fact may be experimentally verified by the following simple means :—Select an iron saucepan lid, sufficiently large when turned upside down to rest on the brim of a moderate-sized flower-pot, then remove the lid, and fill it with burning charcoal; press a lump of pomatum into the aperture at the lower part of the flower-pot, that it may hold water, and, when filled therewith, set it to stand in a large flower-pan; then with the tongs place the lid containing the fire to touch the water and to rest upon the rim of the flower-pot; in the course of a few minutes the heat of contact will cause the water at the surface to boil furiously, and partly overflow into the pan, whilst the water beneath will remain cold, and therefore the pomade will not be melted to permit the flow of water through the aperture.

The experiment admits of the following modifications :—Select another flower-pot, similar to the former; fit a sound cork to the aperture at its lower part, then remove the cork; obtain a lump of ice about the size of a large orange, tie one end of a piece of packthread round this, and pass the other end, by means of a large needle, through the cork from its upper to its under-side; then insert the cork tightly into the aperture, and draw the end of the string until the lump of ice at the other may be brought within the flower-pot, about three inches lower than its brim; set the flower-pot to stand steadily within another, on a large flower-pan, then fill the first with water, and the ice will float to the extent permitted by the string; lastly, set the lid containing the lighted charcoal to touch the water and to rest upon the rim of the flower-pot exactly as before, the same phenomenon of furious ebullition will ensue, and at its cessation, if the fire be removed, and the water quickly poured from the flower-pot, the solid lump of ice will be found, although it was only a few inches beneath the lower surface of the boiling water.

If water had the power of conducting heat, the whole bulk thereof should fairly boil when the heat is applied above, the same as it does when the heat is applied below ; but it is not a conductor of heat, and the theory of its ebullition in the latter case is as follows :—

The heat is conducted through the material of the vessel in which the water is contained, and thus expands the water that it first touches, the portions thus expanded ascend, and impart heat to the upper and colder portions, contract, descend ; gain heat, expand, ascend ; impart heat, again contract, descend, gain heat, expand, ascend, impart heat, and so on, establishing ascending and descending, or convective currents, until every portion of the water is equally heated to a temperature at which it can no longer remain liquid, and accordingly vapour or steam simultaneously escapes from every portion ; vaporization rapidly ensues, or, in plainer terms, the water boils. The whole bulk of the water can never boil when the heat is applied at its surface, because convective or ascending and descending currents cannot thereby be established ; the heated water at the surface is a non-conducting film, but when the heat is applied below, the heated water becomes a convective current.

These convective currents may be detected by a very simple arrangement : place a teaspoonful of fine sawdust in a flask, fill its bulb only with water, close its mouth with the thumb, and shake the flask briskly, that the sawdust may become saturated, and chiefly subside to the bottom, when the flask is suspended by its neck from a string fixed to any convenient support, about a foot above the level of a table. Apply the flame of a spirit-lamp gradually to the lower part of the bulb of the flask, and when its thin glass conducts heat to the water within, such heated water will ascend, and mechanically carry particles of the sawdust with it, which will thus detect its ascent ; at the same time the cold water above will descend, and mechanically carry particles

of the sawdust with it, which will thus detect its descent, and this circulation or convection will continue until the water boil.

The convective currents produced when a liquid is heated from below, may be illustrated by an apparatus, consisting



Fig. 64.

of a thin earthenware bowl, containing water stained of a deep blue colour with sulphate of indigo, the bowl being supported upon a tripod, and a syphon-shaped glass tube, twelve or fourteen inches long, and three quarters of an inch in diameter, filled with plain water, supported so that its two ends, one of which is longer than the other and slightly curved upwards, may dip into the coloured water in the bowl, as represented in the accompanying engraving.

A lamp is then placed beneath the bowl, that its flame may impinge upon that part immediately under the open end of the straight limb of the syphon; the coloured water derives heat from the surface of the bowl to which the flame is applied, it expands and rises, but cannot enter into the curved end of the syphon as its orifice points upwards, but a portion can enter the other, accordingly the warm blue water will gradually ascend in it in the direction of the dart, while its cold colourless water will descend through the other, as also indicated by a dart, so that one limb of the syphon will contain blue, and the other colourless water; the heat of the flame is continued, the blue water reaches the bend, passes over as shown by the curved dart, becomes cooled, and descends through the colourless to the coloured water in the basin, so that both limbs of the syphon thus contain blue water, and illustrate to a certain extent the convective, or ascending and descending cur-

rents established throughout a liquid when heated from beneath.

The arrangement for the performance of the foregoing experiment requires some trouble, but this will be amply repaid by its success, and therefore the construction of the syphon, and the adjustment of all the other materials and agents demand attention.

First, boil about two gallons of clean rain water, in a clean tin saucepan, for about an hour, then remove the vessel from the fire, cover it closely with its lid, and allow the water to cool down to common temperature.

Place half a teaspoonful of powdered indigo in a small gallipot, containing half a fluid ounce of sulphuric acid; stir these ingredients together with a short stem of a tobacco pipe, from time to time, whilst the gallipot is placed upon the warm hob of the grate; in the course of a few hours a liquid will be produced of an intense blue colour, indeed so intense that it appears black, but a single drop stirred into a large teacupful of water will instantly tinge it throughout of a fine transparent blue colour.

Select a piece of glass tube, four feet in length, about the twentieth of an inch in thickness, and having a bore or calibre half an inch in diameter, and perfectly clean; if not so, it can be cleaned by passing a long string, with a little lock of cotton or tow fastened to one end, several times through the tube.

Place a hand near each extremity of the tube, and thus hold it horizontally, that its centre may be at a distance of four or five inches above the surface of a bright charcoal fire, in a small chauffer or brazier; turn the tube round and round between the hands, that it may conduct the heat, and warm gradually at its centre: continue to turn, bring it lower and lower, or nearer the heat, and let it become fairly red-hot for about four or five inches.

The hands will soon detect that the heated part of the tube has become soft and yielding, then, by gently drawing

them together—as if slowly bending a cane—the glass tube will bend from its original straight form; and by still keeping this yielding portion in the heat, and still gently drawing the hands together, the tube will assume the form of a syphon having its limbs parallel to each other, though about four inches apart, and, like a syphon, one of those limbs should be about four inches longer than the other; this inequality of length is managed by originally heating the tube a little beyond its true centre, if, however, the limbs be of equal length the matter can be remedied, of which hereafter.

Having wrought the tube into this bent shape, place its open ends in a box or jar, that its bend may stand uppermost, and thus cool slowly in the air; when it is sufficiently cool to handle, it must be removed, and again heated according to the following directions.

Hold the tube horizontally, that about four inches of its longest end may become red-hot and soft, then, by gently pressing against this with a sound piece of charcoal, or a stick of wood deeply charred, form it into a bend, exactly parallel with the first, though not so large; this being done, place the first bend to stand in the box or jar, that the second bend may cool.

When cold remove the tube, place it flat upon the table, and very probably the straight limb of the tube will now appear the longest; if so, take a sharp “three square file,”



Fig. 65.

and gently make a deep cut across the glass, then hold the red-hot heater of an “Italian iron” on this cut for half a minute, and if the tube do not crack or fly, remove the heater, and touch the file mark with the wetted tip of the forefinger, this sudden cold will cause it to fly across, and by a gentle pull, a short piece of the tube will come away, and the limbs of the syphon will bear the same proportion to each other, as those shown in the annexed engraving.

Select a thin earthenware or tin bowl capable of holding two quarts, and wide enough to admit the two ends of the syphon when placed in it with its bend uppermost; next remove it, and fill the basin with a portion of the boiled rain water, then stain this deeply with a portion of the solution of indigo. Select a shallow pan that will hold the syphon when laid flat within it, pour the remaining uncoloured boiled rain water into the pan, that the syphon may be perfectly filled, and every bubble of air excluded; then place a finger or thumb of each hand beneath the water to close each end of the syphon; thus lift it out, and when both ends are fairly immersed beneath the surface of the coloured water in the bowl, remove the fingers or thumbs, the syphon will remain full of uncoloured water, on account of atmospheric pressure. The bowl thus containing the syphon must be placed upon a tripod stand, and the syphon usually raised into a perpendicular direction, so that the free of its straight end may be half an inch below the surface of the coloured water, and support it at this elevation by a string attached to its upper bend, and fastened to a convenient hook above, as that of a chandelier in the ceiling of a room.

Apply the flame of a spirit-lamp to the bottom of the bowl in a line perpendicular with the straight end of the syphon, and the result will ensue as described at page 354. The object of boiling the rain water is to expel the air from it, if this precaution were neglected, the subsequent introduction of air-bubbles in the syphon would materially interfere with the success of the experiment.

In every case of the application of heat of sufficient degree beneath a vessel containing water, that extraordinary phenomenon is elevated to its boiling-point by convective currents, now inquire the degree of heat that is required for the phenomenon of ebullition to ensue. Provide a mercurial thermometer having its scale graduated above 212°, and immerse its bulb into rain-water contained in a tin cup con-

veniently supported or suspended, so that the flame of a spirit-lamp may be applied beneath; as the water gradually gains heat by convection, the mercury will gradually ascend in the tube, and at length become stationary in it at about 212° , marked as the boiling point of water.

Experimenting at different times upon the ebullition of water, the chemist discovers that its boiling point is liable to variation, being sometimes materially above, and at others materially below 212° .

Searching for the cause of this variation, he detects the invisible though ponderable agency of the atmosphere, whose weight, although constant as an entire volume around the earth, is liable to local fluctuation in its pressure upon terrestrial and aqueous surfaces, on account of the expansions and contractions it sustains by increase and decrease of temperature.

If the weight of the air increase or diminish from its standard pressure, page 145, indicated by the ascent or descent of the mercury from 30 inches on the scale—the boiling-point of water is elevated in the one case, and depressed in the other, because in the former, more heat is required to oppose and overcome the greater pressure of the air, that is tending to preserve the water in a liquid state, than in the latter, where the pressure is lesser and rather tending to facilitate the conversion of the water into vapour.

It is further discovered that at various heights and depths from the level of the sea, water sustains an alteration in its boiling point, dependent upon the rarity or density of the air, which, as mentioned, page 170, decreases in weight as it ascends from the terraqueous globe; accordingly upon the summit of a mountain 15,781 feet above the level of the sea, water will boil at 180° , a temperature inadequate for the proper preparation of food.

At the bottom of a mine 1,650 feet below the level of the sea, water will boil at 216° , a temperature better suited for the preparation of food, by extracting all its soluble nutri-

tious matters, than the ordinary boiling-point, 212° , upon the earth at the level of the sea.

The Almighty has ordained water to sustain changes in the temperature required for its ebullition, and that it should require the highest on the surface, or below the surface of the earth, where its utility is most needed by mankind.

Water maintains its chemical composition, however violently its physical state may be changed by alteration of temperature into ice or steam; and if the latter be prevented in its escape from the water by which it is produced,—by closing the vessels in which the experiment is made—the water rises far beyond its ordinary boiling-point, and the steam partaking of such increase of temperature, acquires an enormous elastic force, and hence is employed as the motive power of the steam-engine, a machine that is working wondrous and strange changes upon the physical, moral, and intellectual condition of mankind.

The Almighty was pleased to prolong the life of the great philosopher who perfected the steam-engine, beyond the allotted boundary of human existence, to the age of fourscore years and four, and then “expressing his gratitude to Providence for that length of days and exemption from infirmity which rendered the evening of his life cheerful and serene, he yielded up his soul in the calmest tranquillity, and passed without pang or struggle from the bosom of his family to that of his God.”

All the foregoing remarkable facts have been established by experiments conducted with the greatest refinement and accuracy attainable by human skill, and in Chemistry, therefore, when speaking of 212° as the boiling-point of water, it is to be understood that such is the thermometric temperature required for the vaporization of water by artificial heat, when the experiment is made with absolute water in a metallic vessel on the earth at the level of the sea, when the atmospheric weight is equal to fifteen pounds per square inch, or is at standard pressure, as denoted by

the column of mercury in the barometer standing at 30 inches, and under such conditions 212° is marked upon the scale of the thermometer as the boiling-point of water.

The manner in which the boiling-point of water is affected by diminution and increase of atmospheric pressure may be experimentally demonstrated by very simple means.

If a portion of water not sufficiently hot to scald the hand be poured into a large ale glass, placed upon the plate of the air-pump, and then covered with the receiver, as at page 166, upon exhausting the air, and thus freeing the water from pressure, it will boil as briskly as though it were placed in a vessel over a lamp; thus imitating the phenomenon that ensues when water is gently heated on the summit of a lofty mountain.

If the action of the pump be suspended, the boiling of the water will stop, because its vapour will then fill the receiver, and the amount of heat yet retained by the water is insufficient to raise it into further vapour against this pressure, which is exactly equivalent to that of the external atmosphere under which the water had ceased to boil before it was subjected to the experiment.

As there are few liquids alike in their specific gravities, so there are few alike in their boiling-points, even when experimented upon at the level of the sea in open vessels under the standard pressure or weight of the atmosphere, and it is discovered that in proportion as saline substances are dissolved in boiling water, so is its boiling-point gradually elevated until saturation be reached, and this perfectly independent of any increase of the pressure or weight of the incumbent atmosphere.

Thus, if pure water be boiling at 212° , and the mercury in the barometer standing at 30 inches, if common salt be gradually sprinkled in, as it dissolves so will the temperature rise, and when the water is saturated with the salt the thermometer will indicate 224° , or 12° above that of the boiling-point of pure water; thus, even spring water has

its ordinary boiling-point a fraction of a degree higher than pure water, and sea water has its boiling-point yet higher, on account of the saline matters both contain, the latter in greatest abundance.

On the other hand, alcohol and ether have boiling-points considerably lower than that of water under similar conditions of pressure, the one boiling at 180° , or 32° below, and the other boiling at 98° , or 114° below the boiling-point of water; accordingly these liquids will boil vehemently at common temperatures when placed beneath the receiver of an air-pump, and relieved from atmospheric pressure by its exhaustion; for it is by such pressure alone that they are preserved in a liquid form at the surface of the earth, and when they are taken to considerable altitudes from the level of the sea, as the atmospheric pressure becomes less and less, so have they a greater and greater tendency to vaporize, though not actually to boil with the evolution of bubbles as in the exhausted receiver, because it is physically impossible for man to take them to an altitude of corresponding rarity.

The experiment of boiling these liquids in vacuo cannot be advised, as their vapours, more especially the vapour of the ether, would corrode or dissolve the oil silk valves of the air-pump, and render a valuable instrument perfectly useless.

Knowledge of the fact concerning the great difference between the boiling-points of water and alcohol, enables the chemist to separate them from each other; take, for example, the combination of the two liquids resulting from their mixture in the experiment illustrating change of capacity for heat, page 163, pour it into the copper boiler of one of the small models of stills that are now so commonly sold; fix on the still-head, insert its tapered beak into the worm-pipe, fill the worm-tub with cold water; place a cotton wick in the small lamp, and nearly fill it with

spirit of wine, depress the wick until only about a quarter of an inch remain above the holder, then kindle it, and place it beneath the boiler; lastly, set a small glass under the end of the worm-pipe that projects from the lower part of the worm-tub.

The heat of the spirit flame—preferable to an oil flame, as it deposits no soot—will soon be conducted by the metal of the boiler to the combination of water and alcohol that it contains, and will effect repulsion between the liquids, the alcohol, requiring the lowest temperature for its ebullition, will rise in vapour the soonest, this vapour will ascend into the globular still-head, and pass from it into the cold worm-pipe, where it will be deprived of heat, or condensed into the liquid state, and soon trickle from it in drops into the glass placed for its reception.

By receiving a few of the drops from time to time upon one end of a slip of folded blotting-paper, and holding this to a flame, the alcohol will kindle and burn with a very pale flame, at length the drops so received will not kindle; this indicates, or in other words is a test, that the whole of the alcohol has distilled, or technically “come over,” and the drops of liquid that will not kindle, consist of the water now boiling and distilling by the prolonged heat of the lamp; the process must be stopped by taking it away, for the analysis or separation is accomplished through the imponderable agency of its flame, the alcohol being collected in the glass, the water remaining in the boiler.

The process of separating liquids from each other, or a liquid from a solid that it held in solution, when practicable by the mere application of heat, is very ancient, and is technically called distillation—from the Latin, *distillare*, to drop, or to run drop by drop—it may be defined as the conversion of a liquid into vapour by an elevation of temperature, and the subsequent conversion of that vapour into a liquid by depression of temperature; in this respect

it differs from sublimation, page 347, yet agrees with it in the fact of the change being merely physical and not chemical.

By the employment of a distillatory apparatus constructed of pure silver, a gentle heat, and exclusion from the free access of air, the chemist is enabled to obtain pure water from sea water, river water, or spring water, the absolute water distilling away whilst the saline and earthy matters, which are not volatile at the same temperature, remain fixed in the boiler of the apparatus.

The evaporation of water from the aqueous portions of the globe, and its subsequent condensation and fall as showers, presents an example of the process of distillation naturally proceeding for the welfare of the animated creation, and such rain water, with the exception of containing a portion of atmospheric air and nitrate of ammonia, is as pure as ordinary distilled water. Although many persons are constantly in the habit of talking about pure water, very few indeed have ever seen it, for to obtain the acid absolutely and chemically pure, solely consistent of elements, oxygen and hydrogen, page 18, to the utter exclusion of all traces of extraneous matter is one of the refined and difficult operations in the whole range of science of experimental Chemistry, and when obtained is quite unfit for human beverage.

Pure, or absolute water, is a perfectly transparent, colourless liquid at all temperatures from 32° to 212° ; it has no taste nor smell; it undergoes no change by any time if kept in closed vessels, the materials of which have no affinity for its oxygen, as for example, in bottles of silver, gold, and platinum; it cannot be preserved for any time in glass vessels, as it dissolves the silica which is one of their constituents.

The unpleasant odour of rain water as it is commonly collected and preserved, depends upon the putrefaction of organic matters that it has washed from the roofs of

buildings, or that it has acquired from the casks or tanks in which it is received and kept, whilst water absolutely pure will remain unchanged for years in the metallic vessels before-mentioned.

In every season, but that of winter more particularly, the very different sensations that we experience upon touching different substances having similar temperature, depends upon their relative conducting power; thus, in a room, a thermometer applied to a silver cup, a glass tumbler, an earthen basin, and a wooden box, indicates that they are all alike in temperature; but placing the hand upon these different objects in succession, the cup feels cold, the glass warm, the basin warmer, and the box warmest; because the metal conducts the heat from the hand with the greatest power, then the glass, then the earthenware, and lastly, the wood, which has so little conducting power that the heat of the hand remains upon it almost at the original point of contact.

If we step out of bed and place our feet upon a carpet, they are not chilled; if we place them upon a floor-cloth they feel icy cold; the one surface being a bad, and the other a good conductor, hence the popular expression of "a warm carpet" and "a cold floor-cloth," although both are of precisely the same temperature, but they differ in texture and also in conducting power.

In this country, the cold of winter is often sufficiently intense to produce dangerous effects upon the living body, destroying its irritability, and depriving it of heat; a person feels an irresistible inclination to sleep; he yields, though against his will, and while lost in insensibility, his limbs stiffen; if thus asleep he be brought into a warm room, the sudden transition causes death; if he be rubbed in the snow he may often recover; the following directions regarding the treatment of persons apparently frozen to death or severely frost-bitten are important to be remembered.

Rub the body with snow, ice, or cold water; restore

warmth by extremely slow degrees; it is highly dangerous to apply heat rapidly, because mortification may take place, since the vessels of the body are too much weakened for the immediate resumption of their ordinary functions.

The temperature of the Arctic regions is frequently sufficiently low—namely 52° below zero—to freeze mercury upon mere exposure to the atmosphere; thus in one of the useless expeditions to those inhospitable climes of ice, a barometer was accidentally broken, a man unfortunately held out his hands to catch the valuable mercury; not only did the intense cold freeze the metal immediately, but the frozen mass conducted so much of the natural heat from his hands, that they were terribly frost-bitten and soon mortified.

The metal mercury, is always liquid even during the most intense cold of winter in England, and for its congelation a chemist is compelled to employ a complicated yet powerful means, of obtaining extreme reduction of temperature—the solution of solid carbonic acid in ether—he then discovers the curious fact that the liquid metal being a conductor, it matters not to what part the cold may be applied, either above or below, it will uniformly contract, ultimately uniformly solidify throughout.

Accordingly if one bottle be filled with liquid mercury and another with liquid water, and the mouths of each be secured; upon placing them simultaneously in a great artificial cold, the mercury when it freezes, contracts and forms a lump that can be shaken about in the bottle whilst the water when it freezes, expands, and forms a lump that will instantly burst the bottle.

Mercury is inadmissible as a thermometric liquid, on account of its anomalous expansion, page 306, when cooled to 0° ; and the two liquids with which thermometers are usually filled are mercury and alcohol; the former has a temperature of 640° for its ebullition, is particularly adapted for indicating ranges above 212° , but on account

of its freezing at 45° below zero, it cannot be employed for indicating ranges below that degree; whilst alcohol which boils at 180° is unfit for higher ranges, but eminently suited for lower ranges of temperature, as it has never been frozen by natural or artificial cold.

When a volume of air is perfectly tranquil at an elevated or a low degree of temperature, its power of communicating heat to the body in the one case is very feeble, and its power of abstracting it therefrom in the other is extremely small; and this appears to depend upon the non-conducting power of the wondrous medium to which reference has been so frequently made during our inquiry regarding the chemical phenomena of the four seasons.

Thus the confined air of a room may be heated by flues to 260° or 48° above the boiling-point of water, yet a person may enter this atmosphere with impunity, though any attempt to remain in it generally occasions difficult breathing and a painful sensation about the eyes, but the skin remains parched and dry.

In some processes of the arts demanding a high temperature, the air of a chamber is often heated to 300° , and workmen who are used to it can enter and remain several minutes without inconvenience.

The temperature of the Arctic regions has been observed so low as 55° below zero during a calm, and at this extreme degree of cold mercury readily froze, yet not the slightest inconvenience was suffered from exposure to the open air by a person well clothed, if he remained still: if he walked rapidly, and thus put the air in motion, it abstracted heat from the body, and produced the most painful sensation of cold.

As confined air is a bad conductor of heat and cold—the terms being merely relative—we immediately discover the use of double windows and double doors both in summer and in winter; the stratum of air enclosed and confined between these contrivances, preventing accession of

heat in the one instance, and that of cold in the other, a fact illustrated, page 154, in regard to the plants beneath a glass-shade.

During the heat of summer, a small quantity of ice may be preserved by placing it in a wooden box provided with a tight cover, and four wooden clump feet, about two inches high, to stand within another box, so that a space of two inches may intervene between its sides and cover; this second box is then closed, and provided with similar clump feet, and placed in a third, leaving the same intervening space; this may be placed in a fourth, and the last closely put down; thus by the bad conducting power of the wood, and the non-conducting power of the intervening strata of refined air, the ice will be prevented from thawing for a very considerable time; and so it may be by enfolding it in many yards of thick flannel, which containing air amongst its interstices, is a very bad conductor.

The non-conducting power of a volume of air may be illustrated as follows:—provide a wide mouthed gallon jar of earthenware, perfectly clean and dry; drop into it a lump of tallow, set it on a table, then place to cover its mouth, a lid containing burning charcoal, as in a former experiment, page 352; let the arrangement remain for ten minutes or a quarter of an hour, then remove the lid, and probably the tallow will be found unmelted.

If air be a non-conductor of heat, why should it so instantaneously expand and contract by increase or diminution of temperature, as it was found to do in the experiments, page 79, at a very early period of this season?

The dilatation of volume cannot result from conduction, convection, or radiation, but probably from the following cause:—the individual atoms of the air in immediate contact with the interior of the glass flask, are suddenly heated by the mere heat of contact into many times their original volume; they do not transmit this heat to other

atoms, yet they do transmit the pressure consequent upon their enlargement of volume instantaneously in all directions; room must be afforded, the whole is a mobile volume, and the whole thus appears to expand by the accession of heat to the atoms of the air which constitute the film in contact with the interior of the glass flask.

Then, upon withdrawing the source of heat, the individual atoms of the air in immediate contact with the interior of the glass flask are suddenly contracted by the loss of heat to it, other portions immediately supply the vacancy, and in their turn are suddenly contracted by the loss of heat, and so on, that the whole volume thus appears simultaneously to contract by the abstraction of heat from the air in contact with the interior of the glass flask.

When a heated solid, such as the red-hot iron-heater, is suspended in the air, several causes are active in lowering its temperature; one may be an extremely feeble conduction by the air, which, for all practical purposes may be disregarded; another is the rapid convection that the heated solid establishes by mere contact with the air; and the third is the powerful radiation that ensues from the heated solid; these two causes, convection and radiation, chiefly effect the reduction of the temperature of the heated body.

The agitation of the air by convective currents, may be proved by admitting a sunbeam through a hole in a window shutter, into a perfectly dark room, and then all the motes contained in the air thus pierced by the light, will be observed in commotion; or the effect may be heightened by sprinkling a little dust of magnesia in the path of the sunbeam, these small particles of light earth will indicate the agitation and unsteadiness of the air, by being mechanically borne about by its convective currents, the same as feathers thrown in the open air denote the direction of the wind, or straws placed upon water, betray the course of its stream, though it may appear to be motionless.

As the air and all gases are thus so extremely susceptible

of alterations in their volumes, by fluctuations in natural or artificial temperatures, it becomes a matter of great difficulty to ascertain their specific gravities with correctness, and experiments upon them must be conducted with all the refinements and accuracies that are known in the science of Chemistry.

The terms heat and cold, are in popular use, and denote the relative state of the body with regard to the temperature of surrounding objects: thus we may imagine an atmosphere so extremely cold, that a mass of ice would impart a sensation of heat; and on the other we may imagine an atmosphere so intensely hot, that a flask of boiling water would impart a sensation of cold.

The sensation of heat and cold, may be produced by the same substance at the same time and at the same temperature; for example:—place three basins upon the table, pour into one of these ice-cold water, into another water at 50°, and into the third, water at 100°; plunge the left hand into the ice-cold water, and the right hand into the water at 100°, let the hands so remain for about a minute, then withdraw them, and plunge both into the water at 50°; the left hand will feel warm, and the right hand will feel cold.

The left hand had heat abstracted from it by the ice-cold water, and therefore when plunged into the water at 50°, experienced the sensation of warmth by the communication of heat from it, whilst the right hand had heat communicated to it by the water at 100°, and experienced the sensation of cold by the abstraction of such heat when plunged into the water at only half the temperature or 50°.

Chemistry discovers methods by which Electricity can be artificially excited in a high degree of power, and this when directed into water will immediately part it asunder into its two gaseous elements, oxygen and hydrogen, in the exact weights that were mentioned, page 18, at an early period of this inquiry.

The manipulations requisite for the success of the experi-

ment of the ultimate analysis of water by electricity—now commonly called the electrolysis of water—may be learned from the generality of popular works on the rudiments of Chemistry or Electricity, and reference is made to these if such information be required, as the full details would lead into a train of discussion and experimental illustration far too extensive for the limits of the present investigation.

Electricity is the only agent by which the two ultimate elements of water can be simultaneously elicited, but there are many other agents that will decompose it by combining with its oxygen, and liberating its hydrogen; a few experiments upon this curious fact may be easily performed.

Select a small clean flask, fill it with rain water, then invert its neck in a finger-glass containing water, as described for the collection of oxygen from growing plants; obtain four or five globules, about the size of peas of the metal sodium, these must be preserved in a small stoppered vial with naphtha, as already directed, page 136, in regard to those of potassium.

Take one of the globules of sodium from the vial, on the point of a penknife, place it on dry blotting paper to absorb the adhering naphtha, afterwards cut it into quarters; its silvery white lustre will be momentarily seen, but will then tarnish or become dull white, on account of the newly cut surfaces becoming oxidated by affinity for the oxygen of the air, and thus forming soda.

Oxide of sodium, or soda, combined with carbonic acid, is found in ancient nitre or natron, constituting native carbonate of soda; and as such it is again found in the ashes of sea-weeds, the same as carbonate of potassa is found in ashes of trees, and from the ashes of sea-weeds sodium is elicited in a manner similar to that by which potassium is elicited from the ashes of trees; so that Chemistry presents the extraordinary fact of the weeds of the ocean and the trees of the earth, each containing a distinct metal, brilliant as silver, and having the strongest

affinities for oxygen of any elementary or compound substances commonly known : let us take advantage of this fact, in the case of sodium, for the decomposition of a portion of the water contained in the small flask.

The globule of sodium being cut into quarters, press each of these upon the blotting-paper to absorb any naphtha, then fold each piece separately, yet tightly, in a bit of thin dry glazed paper, about an inch square, stained of a yellow colour with the tincture of turmeric, page 133; grasp the lower part of the bulb of the flask firmly with one hand, and thus lift it, that its neck may be about an inch beneath the water at one side of the finger-glass in which it is inverted; take one of the packets of sodium between the finger and thumb of the other hand, plunge it very quickly beneath the water, and insert it into the mouth of the flask, relax hold of the packet, and although containing a solid metal, yet, like solid ice, it will rise through the water to the top of the interior of the flask, because sodium, like ice, is lighter than water, or nearly of the same specific gravity as ice; for example, water 1.000, ice 0.940, sodium 0.934.

As the water passes through the capillary pores of the thin paper into direct contact with the sodium, myriads of minute bubbles will rapidly exude from the folds of the paper, and at length a globule of the metal will suddenly burst forth, and appear with a silvery lustre, surrounded by myriads of minute bubbles; the globule will diminish in size, and when very minute, just before it will vanish, it may very probably become red hot, all the minute bubbles will coalesce into one large bubble at the top of the flask, as did those of oxygen evolved by the *confervæ*, page 242, whilst a corresponding bulk of water will descend into the finger-glass.

During this experiment, and indeed all others where intensely active agents are employed, the operator should never approach his face exactly above, or very near to the vessels or apparatus, for explosions or fractures will occa-

sionally happen, and might cause severe or troublesome wounds; indeed, if a fencing-mask with very close wires be worn, it will be an excellent precaution against injury from flying fragments of glass, though not from splashes of liquids; these must be quickly washed away from the parts they touch with abundance of water.

But suppose the experiment to be performed successfully thus far, let the remaining packets of sodium be similarly introduced one by one; when the last has presented its phenomena, pass a cork through the water to close the mouth of the flask, place it to stand on a ring, as already described, and as the oxygen, in the experiment with the *confervæ*, ascended into the neck of the carafe when set upright, so will the *aëriform* matter evolved during the present experiment rise into the neck of the flask.

Let the apartment be darkened, then having kindled a slender splinter of wood, remove the cork, and apply the light to the mouth of the flask, the *aëriform* matter will kindle and burn with an extremely pale lambent flame, cover this instantly with a clean dry narrow ale glass, and its interior will become damp.

The explanation of the whole proceeding is as follows: sodium 24 has an intense affinity for oxygen 8, and when placed in water, instantly decomposes a portion of it = 9, and combines with oxygen 8, to form oxide of sodium or soda 32, which dissolves in the remaining water, and being an alkaline substance changes the vegetable yellow of the paper to brown; but the sodium has no affinity for the other element of the water, namely, hydrogen 1; it is expelled in myriads of globules around the floating metal, and is collected in a pure gaseous state, and kindles upon the contact of flame, combines with oxygen 8 from the atmosphere, and produces the vapour of water 9, which condenses within the cold glass.

From the entire course of the experiments we are presented with the following interesting and important pheno-

mena,—first, the decomposition of water; secondly, the production of soda; thirdly, the solution of soda; fourthly, the vegetable colour changed by soda; fifthly, the eduction of hydrogen; sixthly, the combustion of hydrogen; and seventhly, the re-production of water.

Let the water be now poured from the flask into a perfectly clean basin, and the pieces of paper be removed with a tea-spoon, then set the basin in an oven moderately heated, leave its door open that the whole of the water may vaporize; when this is effected there will be found in the basin a minute portion of a solid, acrid, and caustic substance, that will powerfully change the yellow colour of a piece of moistened turmeric paper to a deep brown; it is in fact soda, or oxide of sodium, not anhydrous though similar in composition to the white crust produced on the metal when its cut surfaces were exposed to the air.

If a globule of sodium be thrown upon the surface of water contained in a shallow plate, part of the water will be decomposed, soda produced, and hydrogen educed as in the flask; but the inflammable element may now be directly kindled by approaching the floating metal with a flame, and thus the extraordinary phenomenon presented of a ball of brilliant yellow coloured fire moving on the surface of water.

If a globule of sodium be thrown upon the surface of hot water contained in a shallow plate, the decomposition of part of the water, the production of soda, and the eduction of hydrogen, will be so intensely vehement, that the latter and part of the sodium will spontaneously inflame.

Potassium surpasses sodium in its affinity for oxygen, and it might be used in the experiment with the flask, but is rather dangerous, as its energetic action often rises beyond control, and shatters the whole apparatus.

So intense is the affinity of potassium for oxygen, that it will decompose water in the solid state of ice; for example, make a hole about half an inch in diameter and one inch deep in a lump of dry ice, drop a globule of potassium therein, it will instantly decompose the portion of ice that

it touches, and thus present the wonderful phenomenon of a brilliant metallic solid bursting into a splendid purple flame upon the contact of cold ice.

Chemistry inculcates reasoning upon the extraordinary powers of these two metals, sodium and potassium, and some others educed from the earths, in so energetically combining with oxygen, in whatever form it may be presented to them, and leads us by analogy to suppose that volcanic eruptions, both on land and at sea, may probably ensue from masses of these metals, or those of the earths, suddenly meeting with oxygen or other elements for which they are known to have powerful affinity, and, thus combining, displaying combustion upon a scale of terrific grandeur and power, for sodium, potassium, and the metals of the earths, are all discoverable, by chemical analysis, in the lavas and scorïæ of volcanic districts.

Water may be decomposed in larger bulk, and its hydrogen educed in larger volume by less expensive metals than sodium or potassium, in the following arrangement of apparatus:—place half an ounce of small slips or fragments of zinc in a half pint narrow mouthed bottle either of flint or green glass, fit a sound soft cork very accurately to its mouth; then remove the cork and perforate it from top to bottom as in a former experiment, page 142; that the perforation may admit from its top, and closely fit for its length, the largest end of a straight stem broken from the bowl of a tobacco pipe; pour sufficient water into the bottle to cover the zinc; no remarkable effect will ensue, then pour in a very slender stream of sulphuric acid, about two teaspoonfuls, a rapid effervescence will ensue, place the cork firmly in the neck of the bottle, that the stem may stand upright, then lift the bottle into an earthenware jar, that will conceal it from sight and only allow the top of the stem to project above its brim, place the whole arrangement on a common table.

After the lapse of three or four minutes, light a slip of paper or a match, hold it at the full extent of the arm,

against the orifice in the end of the stem, a pale lambent flame will immediately arise therefrom, and continue for many minutes, it will be scarcely visible in broad day-light, therefore close the shutters, or otherwise darken the apartment.

Take a large footed glass tumbler, perfectly clean and dry, hold its foot that its mouth may be brought in an inverted position over, and then around, the flame, the dry glass will become damp, and in the course of a few minutes pellucid drops will fall from its inverted brim, until it become very hot, it may then be removed, and the flame will ultimately cease.

These remarkable phenomena may be explained as follows : —zinc 32 has an affinity for oxygen 8, and is capable of combining with it to form oxide of zinc 40, this constitutes the white crust that forms on zinc when melted in a ladle set in the fire, the metal in such case being oxidized by the oxygen of the atmosphere ; a similar crust forms more slowly when polished zinc is exposed to a damp atmosphere, and this is due to the oxygen of the aqueous vapour therein present, but the metal will not rapidly oxidate when placed in water as it was at the outset of these experiments.

The mere contact of sulphuric acid 40, immediately excites zinc 32, to decompose a portion of the water = 9, in which it is immersed, and to form oxide of zinc 40, a secondary compound, page 12, which then combines with sulphuric acid 40, also a secondary compound, to form sulphate of zinc 80, another new secondary compound, which dissolves in the remaining undecomposed water, or primary compound ; whilst from the portion of it which is decomposed, hydrogen 1, is educed, causes the effervescence, escapes from the orifice of the stem, and invisibly mingles with the surrounding atmosphere.

The heat of the lighted paper, however, incites this hydrogen 1 to exert affinity for oxygen 8, which is supplied by the atmosphere to support the combustion, and to pro-

duce hot watery vapour 9, which the cold glass tumbler deprives of heat, and condenses into liquid drops; thus during the experiment, the decomposition or analysis of water by the agency of the zinc abstracting oxygen therefrom, is proceeding in the bottle below; and the composition or synthesis of water by the agency of oxygen imparted by the atmosphere to the heated hydrogen, is proceeding in the glass above.

As the bottle, until the addition of the sulphuric acid, contained a portion of atmospheric air, the object of placing it in the earthen jar, and allowing three or four minutes to elapse before the application of the lighted paper, was that the evolving hydrogen should expel the whole of such portion of air through the orifice of the stem; for had the light been applied to it immediately, the mixture of hydrogen and the air would have kindled suddenly, with explosion, shattered the bottle into fragments, and scattered its contents, to the danger of the operator and the damage of furniture; but should an explosion accidentally happen, the strong earthen jar will prevent any such inconvenient dispersion of materials.

The sulphuric acid undergoes no decomposition; its mere contact induces that of the water by the metal, with the oxide of which it combines to form sulphate of zinc, this remains in solution with the excess of water in the bottle, and if it be decanted therefrom into a clean saucer, and this placed in a warm oven, with the door partly open, that it may be evaporated to about half its bulk, it will, upon withdrawal from the heat and exposure to cold, yield transparent crystals of sulphate of zinc, which may be re-dissolved in water and employed, as at page 319, in the experiment regarding the floatation of liquids upon each other.

How the contact of sulphuric acid induces the foregoing decomposition remains a mystery, it is not, however, a solitary instance of the fact that the mere presence of a substance which itself undergoes no decomposition, induces

the decomposition of another with which it is in contact; it is conventionally said to act by catalysis, or to produce catalytic action, terms derived from the Greek *cata*, *against*, and *luo*, to *loosen*; and with thus denoting the phenomenon, the chemist is compelled to be content until its cause be revealed by experiment.

The definite weights in which the elements oxygen and hydrogen combine to produce compound water have been previously stated, page 18, the definite measures in which they combine may now be mentioned, to impress upon the mind of the young student the enormous volume of gaseous elements contained in a given bulk of water.

When one volume of hydrogen and half a volume of oxygen are incited to combine, the product is not one volume and a half, but only one volume of the vapour of water, page 82, so that there is a contraction of volume, and if this be cooled, it sustains a condensation into $\frac{1}{1690}$ th part to form liquid water.

Chemistry experimentally and incontrovertibly proves that each drop of water contains eight hundred and forty-five times its bulk of oxygen, and one thousand six hundred and ninety times its bulk of hydrogen.

To impress upon the mind of the young student this extraordinary fact regarding the enormous volume of gaseous elements that is included in a drop of water, let 1690 peas, all similar in size, represent one volume of hydrogen, and 845 similar peas represent the half volume of oxygen; then 1690 more peas to represent the one volume of the vapour of water, into which the gases contract by combination, and one pea to represent the drop of liquid water into which it falls by condensation.

It is some little trouble to count so many peas, but once accurately done, the three heaps may be preserved in three bottles, and will be useful for illustrating the volume of gases contained in one drop of water.

This wonderful fact, revealed by the just and proper pur-

suit of pure experimental philosophy, leads us to extol and reverence the Omnipotent Hand, that created these elements, and coerced them within a liquid bond, for the welfare and support of animal and vegetable life; and that could in a moment liberate them therefrom to form an atmosphere of death.

In the earliest ages of the world, it is reasonable to conclude that man sought repose from his work and his labour soon after sunset, but in the course of his numerous avocations he would not be long without discovering that the combustion of various organic productions might be employed not only as sources of artificial light but also of heat.

How the Creator originally permitted to man the wonderful phenomenon of combustion, whether by the effect of lightning, meteors, volcanic flame, or friction of branches, cannot be determined, and will ever remain a mystery: it is certain that man soon became aware of its power, cherished its existence, and devised means of eliciting it at will as an agent for ministering to his wants and comforts.

At this inclement season of the year, when the trees are bare, the streams bound in ice, the earth clothed with snow, the sky obscured by clouds, and the chilling winds howling around our dwellings, we become fully sensible of the comforts of an English fireside; an examination of the chemical phenomena that it likewise presents will bear most intimately upon much of our previous investigations regarding the habitudes of solids, liquids, gases, and vapours, with the imponderable agency of heat.

From our previous investigations it must be evident that the chemist is permitted to discover and to work wondrous and strange changes upon the multitude of organic and inorganic substances that are presented throughout the magnificent Creation; but it is worthy of particular mention, although he may mix and separate, combine and decompose, gather and scatter, be it remembered that he can neither annihilate nor destroy one solitary grain of matter.

The power of annihilation and destruction is vested in the Hand of God, by "whom all things were made, and without whom there was not anything made that was made."

The phenomenon of combustion either naturally or artificially excited, appears a direct contradiction to the assertion of the inability of man to destroy matter, for no expression is more common than that of "destruction by fire;" yet, accurately considered, this destruction is found to be only apparent, and not real.

Fire was anciently regarded as a peculiar distinct principle or element, having a specific or inherent power of destruction, and in this sense it is repeatedly mentioned in many of the most sublime and forcible passages of Scripture; but science has been permitted to discover that fire, so far from being an element, is the invariable result of intense chemical affinity suddenly summoned into action between two or more substances.

During ordinary combustion, the elements of the combustible or inflammable substance, exert affinity for the oxygen of the air, and produce compounds which, in the generality of cases, are gases or vapours, and therefore elude observation, but they admit of detection by the chemist, and from them he can educe elements, the sum total of which is exactly equal to the original weight of the combustible or inflammable substance.

Therefore he is compelled by the result of experiment to conclude when a substance is burned, or apparently destroyed by fire, that its physical form alone is changed, but its elements are unchanged, they have been induced by the elevation of temperature to relinquish their original affinities and to assume new, but definite arrangements, which in all ordinary cases are the compounds known as carbonic acid and water, both being in the state of heated vapours.

Such compounds are ordained to mingle with the atmosphere, and upon subjection to the recondite powers of

vitality are decomposed, their elements secreted by vegetation to form woody fibre and other organic matters, which may be again employed as fuel, which will again produce the same compounds, and so on perpetually travelling, and illustrating at every change of their affinities the indestructibility of matter, and the power and beneficence of its Creator.

All substances of organic origin are combustible, but all are not equally suitable for employment as fuel for the production of light and heat; Chemistry, extending its researches, regarding the oils expressed from seeds or fat, obtained from animals, discovers them to be precisely similar as regards their elements, viz., carbon, oxygen, and hydrogen, the latter element being in excess, and conferring extreme inflammability upon their vapours.

By a beneficent provision of Providence, they do not contain nitrogen, were it present, these proximate principles, vegetable oil and animal fat, could not be advantageously used as fuel for the production of artificial light or heat, as during their combustion, in addition to carbonic acid and water, they would produce ammonia and other volatile empyreumatic vapours, the odours of which would be as intolerable as that emitted from burning flesh.

Wood is invaluable as fuel because it does not contain nitrogen, and the same remark is applicable to many of the best and purest varieties of coal, some varieties do contain a small portion, but very slight inconvenience is experienced by the production of ammonia, when such coal is burned in the usual manner, the hurtful vapour being soon diffused throughout the enormous volume of the atmosphere, and is destined to yield its nitrogen to the vegetable kingdom.

The materials generally laid in a fire-grate are paper, wood, and coal; there is much science in this apparently simple arrangement, for they are laid in the order of their relative combustibility, they are all closely allied in chemical composition, but they differ in mechanical aggregation, paper being fragile, wood tough, and coal brittle.

A lighted match, applied to the paper, causes its rapid inflammation, this kindles the wood, which does not burn so rapidly on account of its closer aggregation, and therefore allows sufficient contact of its flame to excite the combustion of the closely aggregated coal, this soon ensues, the fire burns well, the smoke and vapour swiftly ascend the chimney.

At first sight it does not appear why a fire should not be kindled as readily at the top of the grate as at the bottom, but daily experience shows us this cannot be advantageously done, and for a simple reason which may be illustrated as follows:—fold a long strip of paper into the form of an ordinary allumette, kindle one end of this, hold it horizontally, the flame will ascend powerfully from its upper side; and however it may be held, the flame will always ascend, and most rapidly when the paper is held with its kindled part pointing downwards.

The flame cannot burn without air, and as it chemically withdraws oxygen from such portions of this wondrous medium as are in immediate contact with it, the action mechanically disturbs the natural equilibrium of fresh or unchanged portions at some distance around and below; these accordingly move swiftly onward and upward, to supply the deficiency occasioned by the flame; and it, consisting of volatile matter, is urged by the force of such moving air into a pointed shape, distinguished as pyriform.

The reason, then, of kindling fuel in a grate at its lower bars, is that the flame may assume its pyriform, and ascend with its own heated products, amidst the wood and coal to induce their combustion, then all its products ascend the chimney and emerge from thence into the external atmosphere; if this be calm, they will continue to ascend and expand through it in the form of an unbroken column to a very considerable extent, before they are totally dissipated, whilst fresh air enters the room to supply the fire with oxygen for the support of its combustion, and the formation

of the heated products, which are principally carbonic acid, and aqueous vapour, mingled with carbon that is educed and not consumed, unless the draught be powerful, but on account of its minute state of division is mechanically borne upwards by the heated products and heated air that rushes into the chimney.

On the other hand, if the fuel were laid in the grate in an inverted order, the paper uppermost, this when kindled would immediately obey the impulse of the air, and ascend in flame with such rapidity that the wood, unless extremely thin, would not gain sufficient heat to inflame, and even if it did, its flame would ascend with nearly equal rapidity, and not kindle the more solid coal.

In all ordinary cases of the employment of coal as fuel, a portion of its carbon passes away unburnt in the ascending draught of the actual products of combustion; this carbon constitutes the principal part of the black smoke, yet being highly heated, it generally ascends and floats for a considerable time throughout the atmosphere.

Remark the black volume of smoke that issues from the lofty stack of a brewery or gas-work, how it ascends, how far it travels through the calm air without appearing to blend amidst its transparent volume; the carbonic acid and aqueous vapour contained in such smoke do really blend and dissolve, but the solid unburnt carbon cannot do so, it therefore remains mechanically diffused for a considerable time until it be cooled, and then precipitates in the well-known form of "blacks."

On the other hand, remark the white cloud of steam that issues from the funnel of a locomotive engine, with what force it ascends in the air, then expands and divides into small clouds; but these immediately vanish; they do not remain floating and travelling like the black smoke, because they consist of aqueous vapour, nearly pure in a state of incipient condensation, and therefore chemically dissolve in

the air without altering its transparency, exactly the same as natural clouds or mists will dissolve, and become invisible in the atmosphere.

Smoke, therefore, presents an example of the mechanical diffusion, and steam an example of the chemical solution, of a substance in the atmosphere: again, the earthy dust of summer, and the snow-flakes of winter, present examples of diffusion throughout the atmosphere, and when either fall, examples of precipitation from such medium; but the solid dust can never ascend again, unless by the mechanical impulse of the currents of air, whilst the solid snow-flakes first change into the liquid, then into the vaporous state by the chemical agency of its heat, and their water is again received and dissolved in its transparent volume.

Returning to the chemical phenomena presented by an ordinary fire; it is of the utmost importance that the products and educts of its combustion should have free and perfect escape, and also that as much, or even more air enter the room than the fuel consumes or is wafted into the chimney by the action of its heat; if this admission of fresh air be impeded or prevented—by nailing leather around the doors, placing sand-bags at their thresholds or upon the lower frames of the windows—the smoke will not ascend, it will descend from the fire-place, being impelled to do so by a current of the external atmosphere which enters the chimney-pot, as the most ready passage for admission to supply the deficiency of the air in the room.

The admission of cold or fresh air to the lower part of a room for the supply of the burning fuel in the grate, without producing the inconvenience of a cold draught, is one of the most difficult chemical problems for practical solution that can well be presented; the simplest plan is to carry an open tube five, six, or eight inches in diameter, from the hearth into the external air, or at all events the air should gain admission at or near the floor, and not at or near the ceiling of the room; this latter situation being most suited

for the egress of air when heated and vitiated by the combustion of candles, oil, gas, and the respiration of the inmates of the apartment.

The greater heat of the air at or near the ceiling of a room, in comparison with that upon or near the floor, is directly felt by a person ascending a pair of steps; as, for example, to reach a book on the highest shelf of a library; and a further proof of its heat and vitiation may be gained by witnessing the languor and dulness manifested by delicate birds confined in cages suspended in a room at a great height from its floor.

The fact of heated air ascending to, and remaining at, the ceiling of a room, furnishes a hint for the most judicious construction of a fire-place, and it would be a matter of difficulty to point out any part of our domestic edifices,—save the drains and sewers—which exhibits such a total absence of rational or scientific principles as an ordinary fire-place and its appendages.

It is common to see large straggling ill-contrived grates placed at a considerable height from the hearth-stone, and in many cases actually half way between it and the mantel-piece, within a most capacious chimney throat; the absurdity of such an arrangement will become obvious upon the slightest reflection.

It must be borne in mind that the heat from burning fuel—like solar heat—radiates into the air without imparting heat to its transparent volume, but impinging upon opaque solid surfaces it is absorbed, and from them communicated to the air in their contact; accordingly, the heat radiating from burning fuel, placed in a grate situated as just described, would chiefly impinge upon, and be absorbed by the walls, the furniture, and other solid objects at, or about its own level, these objects would impart a portion of it to the air in their vicinity, then the principal volume of such warm and expanded air would quickly waft into, and ascend, the capacious chimney, and the remainder would rise to,

and remain at the ceiling, where its presence is by no means needed, whilst an under current of cold air would enter beneath the doors or through other crevices at the floor of the room, to restore the equilibrium disturbed by the burning fuel, and doing so would produce the well-known disagreeable and dangerous effect of "a draught."

A person seated in front of the fire in such a grate, would be scorched from his face to his knees through the arrest and absorption of the radiant heat by his opaque clothing, whilst his legs and feet would be chilled through their immersion in the under current of cold air, or more popularly the "cold draught;" with the view of preventing this annoyance, every chink and cranny, even the key-hole, is sedulously and tightly stopped with cloth, and then it is discovered that "the fire will not draw," but the smoke will descend the chimney, and roll its sooty volume into the room, for a reason already mentioned.

Accordingly a door or window must be partially opened to admit fresh air; this after a time will urge the smoke to return into the chimney, but every article of furniture, particularly the draperies of the room, will remain soiled by the soot, and impregnated with its odour; ultimately, when the room is clear of smoke, if the door or window be closed for a few seconds, it will roll in again, and fill the room exactly as before, so there remains no alternative but to keep either the one or the other, perchance both, open, and the occupants of the room will very shortly suffer from the effects of a severe cold, induced by sitting in "a thorough draught."

It has been experimentally demonstrated, and frequently mentioned, that the atmosphere is not a conductor of heat, and only admits of having its temperature elevated by the establishment of convective currents throughout its volume by the direct contact of heated surfaces; this fact holds equally good in the dominions of Nature, and the provinces of art.

A proposition to warm a room comfortably by the heat of a fire placed in a grate at the ceiling, would be deemed absurd, yet its practical situation in ordinary is complacently regarded, although nearly equally absurd; for it is actually at a very considerably height from the floor, and therefore the result approximates in no slight degree to that which would ensue if it were placed near the ceiling, viz., keeping the air at its own elevation very hot, and that beneath it very cold; for warm air will float upon cold air in artificial volumes, the same as hot water will float upon cold water in artificial bulks; the latter facts have been proved by the experiments detailed at page 352.

For warming an apartment to any comfortable temperature by an open fire, the grate should be placed as close to the hearth-stone as possible; it should be wide and shallow, and not consist of any needless amount of metal, and inserted between sides of stone or fire-brick, the whole aperture for its reception, contracted from its usual width, and lowered from its usual height, and a pipe provided for the admission of the external air to the upper surface of the hearth-stone.

By this arrangement, heat will radiate chiefly to the floor, and be absorbed by the hearth-rug, carpet, or other articles of furniture, these will impart heat to the air that may enter along the floor, and therefore, instead of its proceeding as an abrupt cold draught directly towards the fire, it will become warmed and diffused in its passage, convective currents will be established, "the fire will draw well," and a genial temperature be soon produced throughout the apartment.

It frequently happens, in defiance of every contrivance, that the smoke will not ascend properly on account of the extremely narrow and tortuous form of the chimney or flue, or its chimney-pot being less elevated than that of a neighbouring chimney, and accordingly a slight wind will blow the smoke from the latter down the former, and it will deliver such smoke to the room.

A similar undesirable result will ensue when the fire is extinguished in the grate to which the shortest chimney belongs, more especially if the apartment be connected with another by folding-doors, as a dining-room with a drawing room in some houses, and a fire kindled in the grate of the latter, for as its smoke ascends, the external air will prefer to enter the apartments freely through the large cold chimney of the dining-room, and to introduce at the same time the odour of its soot, and a volume of any neighbouring smoke, rather than to seek a more limited or difficult entrance beneath the crevices of doors from the hall or passage.

It would lead into a field of inquiry far too extensive for the present general purpose, to detail the principles upon which fire-places and closed stoves may be scientifically constructed, as likewise the contrivances for permitting the escape of foul or vitiated, and the entrance of fresh or pure, air; suffice it to state, the main fact requiring attention in warming by hot air, is to admit a large volume moderately heated and hydrated, that may slowly and equably diffuse itself throughout an apartment, and not to admit a small volume intensely heated and anhydrous, for by the latter proceeding, instead of the whole air of an apartment being equally elevated in temperature, scorching blasts would occur in one part and freezing draughts in another.

It must be granted that the practical application of scientific principles to the methods of warming and ventilating domestic edifices and public buildings is always difficult, and frequently abortive; therefore, after incurring vast inconvenience and enormous expenditure for hot-air stoves and flues, the old English fireside is at length gratefully sought, although snow-flakes may fall from the wintry air, through its ample chimney, whilst bright flames rise from the burning "yule log" on its glowing hearth.

The extraordinary and invaluable mineral substance, so popularly known in England as coal, presents, upon che-

mical analysis, the same ultimate elements as wood, and occasionally a small amount of nitrogen; this fact induces many of the greatest philosophers to imagine that coal consists of the remains of gigantic forests, which were overthrown and buried in the earth at the time of the Deluge.

The extreme importance of coal as fuel, consists in its being extremely hard and compact, and therefore incapable of consuming with great or unprofitable rapidity: a lump of coal placed upon a clear fire is some time before it will kindle perfectly, whilst a shovelful of fine coal-dust thrown on the fire will instantly kindle as a large and dangerous flame, thus affording another illustration of chemical affinity being excited when attraction of aggregation is mechanically overcome. When a fire of coal is in perfect combustion, a fine yellow flame blazes steadily around its surface; this is due to the burning of the hydrogen and a part of its carbon, and the latter being solid, is the cause of the great light of the flame, for that of gaseous hydrogen, as we have discovered, page 375, is extremely pale.

Chiefly from the lumps of coal in close contact with the hottest bars of the grate, suddenly issue hissing streams of greenish-yellow vapour, and often kindle, producing jets of brilliant yellow flame, or will do so upon contact with a lighted piece of paper; these phenomena admit of chemical explanation.

The iron bars become heated and impart the heat to the interior of the lumps of coal, such heat causes part of the coal to decompose, and produce volatile gas and vapour, which cannot there burn for want of air; at length it is produced and accumulated in such quantity and of such elastic force, as to burst through the weakest part of the interior of the lumps, and issue into the air, in which it escapes unburnt, if the temperature be not very high, as a greenish-yellow vapour, or kindles at the heat of the surrounding glowing coals, or at that of the lighted paper, and burns as a brilliant yellow flame.

Chemically speaking, when coal is heated out of the access of air, it is chiefly resolved into a large volume of vapour, called carburetted hydrogen, though containing more carbon than the gas obtained from stagnant water, and from the observance of the simple fact of its production by heating coal, originated the gigantic manufacture of "coal-gas," as it is popularly called, for artificial illumination.

The discovery of coal-gas was made by a chemist upwards of a century ago, but it was considered as a mere curiosity of the laboratory; its practical application to artificial illumination was not entered upon until within the last forty years; the merit of this stupendous undertaking is divided amongst a host of scientific men, whose names adorn the philosophical annals of this country, and who must be considered as real benefactors to mankind, for the bright illumination of our towns and cities has contributed a most effectual share towards the prevention of many deeds of darkness.

The merit of first conducting, upon a comparatively large scale, the analysis of different specimens of coal, of ascertaining the volume of gas produced from equal weights of these, the heat most adapted for the production of gas, its purification, its illuminating power, and the construction of the argand-burner for its combustion, is solely due to a philosopher of the present day, who, educated in the same school of inductive science as his great predecessor—unto whose memory a feeble though sincere tribute of respect has been paid, page 107,—has adorned the science of Chemistry with many other important experiments and discoveries, more particularly in that department relating to the recondite functions of organized beings, and to the extraordinary nature of organic products, and whose extensive, varied, and sound information concerning the whole of the science is unsurpassed; and, until his retirement from the lecture

table, his clear and explicit manner of teaching the facts of Chemistry by lectures was certainly unparalleled.

To this philosopher the writer of these lines is indebted for his first instructions in Chemistry, and his introduction to many luminaries of science, some of whom have been recalled by the Almighty from their ardent investigations of the wonders of the Creation, but a few are yet permitted to continue their ennobling pursuit, and to adorn the annals of experimental philosophy with facts and discoveries of the utmost practical value and importance.

Returning to the fuel from whence emanated the vivid jets of gas which led to the above passing notice of its production and application on a large scale to purposes of practical utility, we may discover when the hydrogen and part of the carbon are evolved as gas, and afterwards consumed, that the bright yellow flame ceases, and a great excess of carbon, containing no volatile matters, but generally contaminated with fixed earthy matters, next enters into combustion, constituting the glowing of the cinders, and only produces the vapour of carbonic acid, which being invisible, the fire is popularly said to "burn clear."

This phenomenon more particularly occurs during a frosty night, because the external air being extremely cold, and that of the room extremely warm—comparatively speaking—the latter rushes towards the fire, and fans or blows it with greater force in its rapid endeavour to escape through the chimney to the cold air without, than it does when there is not so great difference between the temperature, and of a consequence, the specific gravity of the interior and the exterior atmosphere.

A beautiful pale blue flame often appears upon the surface of the red-hot glowing cinders; it results from carbonic acid produced in the lower portions of the fuel in its ascent through the upper, combining with more carbon, and

changing into an inflammable compound called carbonic oxide gas; page 30, the same flame also appears on brick and tile-kilns which are heated by the combustion of coal ashes, and in such situations it has been occasionally mistaken for the "*ignis fatuus*," especially on dark nights.

The blue flame of carbonic oxide gas is supported by the oxygen of the air exerting affinity for, and combining with, the excess of carbon that it had just derived from the fuel; thus carbonic acid vapour is again produced, and this is the reason that a piece of paper or a shaving of wood, cannot be lighted with readiness on the top of a cinder fire; the heat may be sufficient to char the paper or shaving, but neither can inflame because enveloped in the carbonic acid which is slowly rising; if this be quickly dissipated by the breath, or the draught produced by the sudden opening of a door, the paper or shaving is fanned into flame by the contact of the air.

If a piece of paper be held amidst the glowing cinders near the bottom bars of the grate, where the fresh air first arrives, it will generally kindle immediately, but it will not do so if the cinders be only dull red-hot, because such degree of heat, although capable of producing volatile matter from decomposing its lignin, is incapable of kindling such product; indeed it requires a white heat for its accension; this is obtained either by fanning or blowing the fire, to excite more rapid chemical affinity between the elements of the fuel and the oxygen of the air, and it is attended by a proportionate increase of temperature.

It is common to hear of thatched buildings, barns, corn-ricks, and hay-stacks being accidentally set on fire from the wadding of a gun incautiously discharged near them lodging in the thatch; the glowing wadding may not be sufficiently hot to do this immediately, but by remaining therein for a short time, is fanned by the breeze into flame, which it then instantly communicates to the surrounding combustible

matters, and soon involves them all in an extensive conflagration.

The bright and dark spots presented in a cinder fire depend upon the intensity of the combustion of some portions of the fuel being greater than that of others; these are liable to infinite variations by fluctuations in the draught of the air proceeding towards the fire, and the ascent of the products of its combustion; whilst watching these variations in the appearance of the fuel on a winter night, the imagination soon becomes active in discovering grotesque resemblances between their forms and those of familiar objects.

When the greater portion of the volatile constituents of coal are expelled by the action of artificial heat with only limited access of air, it becomes "stified coke," and this chiefly consisting of solid carbon is a form of fuel eminently calculated for the reduction of iron and other metals; it burns with intense heat, and contains no sulphur, which "gas coke" invariably does; hence the peculiar odour of burning brimstone emitted from ordinary coke fires, if the draught of the chimney be not rapid and powerful.

The utility of coal as a source of artificial heat and light is too well known for comment here; the wisdom and beneficence of the Creator displayed in the occurrence within the earth of extensive strata of coal, where forest trees are but few upon its surface, calls forth our admiration and gratitude.

In England, "a land whose stones are iron and out of whose hills thou mayest dig brass," page 291, as wood fuel is scarce, these ores could not be obtained without the aid of coal to burn, and heat water to produce steam as the motive power of the engine to draw them from the mine, neither could they be reduced to the metallic state without the agency of coal and limestone.

The Creator in His wisdom and beneficence, has asso-

ciated the most abundant ore of iron—carbonate of iron or iron-stone—with the limestone and coal required for its reduction to yield metallic iron.

The incessant demands that are made for coal as fuel for domestic purposes, metallurgical operations, steam-engines, and also for the production of gas, compel the miner to descend to greater depths within the strata of the earth, and to encounter greater perils than were formerly needed to obtain this invaluable mineral treasure, and most particularly on account of the air of the coal mine being rendered explosive by a gaseous exhalation of carbon and hydrogen, similar in composition to the carburetted hydrogen, page 247, evolved from stagnant water.

This exhalation of inflammable carburetted hydrogen gas in coal mines is called the fire-damp, to distinguish it from that of carbonic acid vapour, which frequently occurs in chalk pits or limestone quarries, and is not inflammable, but produces instant suffocation, page 278, and is therefore called the choke-damp.

The fire-damp was long unconquerable, and the most terrific explosions of its mixture with the air of the mine on the contact of the flame of the candle necessarily employed to afford light to the subterranean labourers, were constantly taking place, attended with the loss of valuable lives and the destruction of expensive machinery, but the Almighty, who ordained its presence in the mine, permitted the philosopher, of respected memory, page 107, to reflect, examine, and experiment upon its habitudes and composition, and ultimately to succeed in effecting its subjection.

From a statement already made, page 391, it is evident that flame requires a very high temperature for its existence, or else spontaneous combustion would commonly occur during the heat of summer, page 172, and from experiments that have been performed, pages 110-12, it appears that metals are the best conductors of heat.

These facts were reasoned upon thus :—as flame requires

a high heat for its existence, and as metals are the best conductors of heat, they, when applied to flame, should deprive it of heat and cause its extinction.

Experiment proved this reasoning to be correct, and its practical application immediately followed for illuminating a coal-mine, the air of which was rendered explosive by the fire-damp.

The flame of a candle was enclosed by a cage of metallic gauze, through the meshes of which the fire-damp might pass, kindle at the candle flame, and burn within the gauze prison, but could not escape therefrom in a state of combustion to explode the surrounding atmosphere, because the conducting power of the metal, deprived it of the heat required for such accension, and thus was a fiery enemy reduced to a fettered slave.

The principle of this inestimable invention, called "the miner's safety-lamp," may be experimentally demonstrated by the following simple arrangement; indeed it is the form in which a flame was first protected from kindling the fire-damp in a coal-mine.

Provide a cylinder of fine wire-gauze, such as is used for making sieves and window-blinds—let it be about ten inches long, two inches in diameter, and closed at one end with the same material; take a lump of soft clay and mould it around the middle of a candle; light its wick; then cover the flame with the wire gauze cylinder, and press its edge firmly down into the clay.



Unscrew the burner of a gas-lamp, and substitute for it a piece of flexible gas tubing about two feet in length, and half an inch in diameter, connect one end firmly, either by its own elasticity, or by tying it with string, to the screw part of the pipe from whence the burner was removed; then hold the tube horizontally, turn on the gas, and allow it to blow from the open end of the tube against the lower part of the wire gauze

Fig. 66.

cylinder, that is imbedded in the clay by which the arrangement is held in the hand.

Immediately upon the entrance of the gas—closely allied in chemical composition to the fire-damp—it will kindle at the flame of the candle, and by moving the cylinder nearer to, or farther from the tube, the combustion within will assume various degrees of intensity, but the flame that it produces will not escape to kindle the gas that is issuing from the tube, and which artificially imitates the jet or blower of fire-damp which naturally occurs in a coal mine.

A lamp is more convenient than a candle, and to the safety-lamp we are indebted for the principal part of the coal that is extracted from the strata of the earth, for the success of the greater number of metallurgical operations, for the chief part of the iron employed in the stupendous works of engineering, for the gas introduced to illuminate our residences, and for the genial heat which ministers to the comforts of an English fire-side.

The true philosopher and philanthropist who invented the safety-lamp, with characteristic liberality, presented it as a gift to his countrymen; and when pressed upon to monopolize the profit of the invention by patent, he declined to do so in conformity with the high minded resolution which he had formed upon acquiring independent wealth, of never making his scientific eminence subservient to pecuniary gain.

These were the words of his reply—"I have enough for all my views and purposes; more wealth might be troublesome, and distract my attention from those pursuits in which I delight; more wealth could not increase my fame or my happiness."

Such was the man, the philosopher, the philanthropist, who, like the great improver of the steam-engine, "with the force of an original genius early exercised in philosophical research, enlarged the resources of his country, increased the power of man, and rose to an eminent place among the

illustrious followers of science, and the real benefactors of the world "

Where is the national monument to his memory ?

In vain do we seek it in cathedral or abbey, and yet in one or other of these hallowed localities it surely should be found ; " not to perpetuate a name, which must endure while the peaceful arts flourish, but to show that mankind have learnt to honour those who best deserve their gratitude."

Quitting these interesting and important matters, which have been developed by the science of Chemistry, and practically applied to the arts of life, attention must be directed to the consideration of a few wonderful natural phenomena, which are conducive to the comfort and welfare of the animated Creation.

The miraculous provision made by the power and beneficence of the Almighty for the protection of His creatures in all climes and seasons, calls forth our admiration and gratitude.

The vital heat of animals is preserved by the wonderful non-conducting clothing that grows from their bodies in form and texture admirably adapted to the temperature of the climate they are destined to inhabit, and mysteriously renewable when partially injured by accident, or wholly decayed at certain appointed times and seasons. In tropical climates the hide of quadrupeds is covered with close thin hair ; in higher latitudes it is thick soft wool ; in the polar regions it is shaggy and coarse on the exterior, but short and fine beneath.

The bodies of warm blooded animals who inhabit the deep are externally surrounded with thick non-conducting blubber or fat, as exemplified in the whale and the seal, and this defends them from the cold of the wave.

The plumage of birds is of various degrees of texture in tropical climates, and it is generally compact and close ; in climates more distant from the equator it is bulky and flocculent, but invariably so disposed to preserve a suitable

degree of warmth, confer buoyancy, and present but little opposition to the atmosphere, throughout which they wing their flight.

The plumage of aquatic birds is also admirably arranged; the coarser feathers having their interstices filled with soft non-conducting down, the whole imbued with an oily secretion, to render them eminently repulsive of the water, page 227, and protective against its low temperature.

The skins, furs and fleeces, of quadrupeds, and the plumage of birds, are stripped from their bodies by man, in order to form garments and coverings for his own protection from cold.

The Hand of Providence is ever extended for the welfare of the mightiest and the lowliest of His wondrous works; thus in many instances it is ordained that animals of the same species, inhabiting countries of different latitudes, should change the texture and the colour of their organic clothing to suit the temperature of the atmosphere, and to accord with the prevailing hue of their haunts.

Thus in England, the skin of the common stoat is covered with thin hair of a greyish brown colour; the texture is adapted to the temperate climate, the hue to that of the localities in which the creature lurks; by this assimilation it derives concealment from its prey and also from its foes; but in Siberia the skin is covered with thick fur, which is pure white—with the exception of the tuft at the extremity of the tail which is deep black—the texture is adapted to the frigid climate, the whiteness to that of the snows in which it dwells, and by this assimilation, derives both concealment from its prey and from the trappers who seek to destroy the life of the animal for the sake of its humble fur, which they exalt into “ermine;”—strange that the fur of a timid animal, and the web of a creeping worm, should be selected to form a robe for the personal adornment of man in the height of temporal power and pomp!

"He sendeth forth His word, and melteth the snow."

As we discovered the transition of flowing water into solid ice to be a slow and gradual process, so shall we discover that the conversion of solid ice into flowing water is unattended by sudden and abrupt disturbance of physical state, and thus gain another proof of the wisdom and beneficence of the Creator, and of the miraculous order and harmony of His works.

A few experiments of the chemical laboratory will serve as introductory to the extraordinary phenomena attendant upon the liquefaction or thawing of ice and snow.

Place a lump of clean dry ice in a basin, carry this into a warm room at the temperature of 70° , for example, the thaw of the ice will commence and continue; immerse the bulb of a thermometer in the water resulting from the thaw or liquefaction, it will indicate 32° , and will constantly again and again indicate 32° whilst a particle of ice remains; when the ice vanishes, the water will gradually acquire the temperature of the room.

During the progress of the thaw, heat must be entering and unbinding the solid form of the ice; but strange to say, it does not elevate its temperature in the slightest degree; it merely causes liquefaction, or in other words, the sensible heat of the room combines with the ice to produce liquid water, and is then rendered insensible to the thermometer.

This habitude of heat is denoted in the science of Chemistry as combined heat, hidden heat, or more commonly latent heat, and most important results of its agency are discoverable throughout the realms of Nature and the provinces of art.

Select two wide-mouthed glass bottles, of similar size and thickness, and resembling each other in all respects as nearly as possible; put into one bottle a pound of clean dry ice at 32° , broken into small pieces, and pour into the other bottle a pound of water at 33° , place the bulb of a thermometer, as at page 157, in each bottle, then carry both

bottles into a room having a temperature of 47° , set them side by side, they will thus be placed under similar circumstances as regards the heat of the room, and they differ only in the physical nature of their contents, the one holding solid, and the other liquid water.

Preserve the air of the room undisturbed by draughts, observe the thermometers at short intervals, note the progress made by the contents of the bottles in heating; if the liquid water arrive at 40° in the course of one hour, the solid ice will not melt into liquid water, and arrive at 40° , until twenty-one hours elapse.

The heat of the room is uniform during this time, but twenty-one times more of that heat are required in the one case than in the other to produce the sensible thermometric temperature of 40° .

To place this easily ascertained, yet most extraordinary fact in another point of view, suppose that during the twenty-one hours the water received heat, as regularly as during the first hour, namely, 7° , or from 33° to 40° , the whole heat would be expressed by twenty-one times seven, or 147° .

The difference between the gain of temperature by the water and by the ice is therefore 140° , hence 140° become the expression for the amount of heat which disappears, which is combined, hidden, or rendered latent during the liquefaction of ice; heat enters the ice, unbinds its solid form, and renders it liquid, but does not produce the slightest elevation of temperature.

To proceed further with this interesting investigation of latent heat—mix one pound of snow at 32° with one pound of water at 172° , the snow will instantly melt, and two pounds of water will of course result—of what temperature?

We might reasonably answer; two pounds of water at 102° , or half way between the original extremes of 32° and 172° ; but the introduction of the bulb of a thermometer will indicate the temperature to be only 32° , or in other

words, that the water is ice-cold; thus the warm water, in cooling from 172° to 32° , loses 140° of heat, which heat converts the snow into liquid water, most certainly, but produces no elevation of temperature.

Such is the remarkable fact thus elicited by actual experiment, and therefore in Chemistry, liquid water is often stated to be a compound of ice, and 140° of heat.

The effect of heat upon any form of solid water, as ice, hail, snow, and frost, is not to raise thermometric temperature during the thawing, but merely to produce flowing water, then, this being wholly effected, rise of thermometric temperature ensues, and continues until the water acquires the temperature of the source of heat unto which it is exposed.

The most acute, the most profound reasoning could not enable us to predict such an extraordinary result, but it is only one of the many wonders revealed by chemical experiment, and from it is deduced the following general law:—

“That in all cases of liquefaction a quantity of heat, not indicated by, or sensible to the thermometer, is absorbed or disappears, and that such heat is withdrawn from surrounding bodies, leaving them comparatively cold.”

This law may be strikingly illustrated in melting a solid substance by the intervention of some chemical affinity, without the direct application of heat; thus, for example, to effect the solution of salts, such as common salt and nitre, they must be melted, and they actually do melt, in the latent heat of the water in which they are placed: therefore the act of solution is attended by depression of temperature.

Place an ounce of finely-powdered nitre in an ale-glass filled with water, promote the rapid solution of the substance by stirring with a spoon, then introduce the bulb of a thermometer, it will indicate great reduction of temperature; and so will the exterior of the glass, for it will summon the watery vapour that is present in the atmosphere

to condense upon its surface as dew ; a dew point is thus obtained by the cold produced by the solution of the nitre, as it was obtained by the evaporation of the ether in the experiment with the hygrometer.

The chemical composition of water is not altered by its transition into ice, neither is its affinity for various substances suspended by such change ; and, although it may feel cold to the touch, it contains latent heat ; indeed, two lumps of ice have been fairly melted by rubbing them against each other.

When finely powdered ice or snow is mechanically mingled with finely powdered common salt, the two substances instantly exert chemical affinity for each other ; they melt, heat is absorbed to cause the melting or liquefaction, and the resulting solution or brine, has a temperature 32° below the original temperature of the ice or snow ; or, in other terms, the mercury of the thermometer contracts and falls to the 0° of its scale, when its bulb is plunged into this freezing mixture, that has been so frequently employed as a convenient source of cold throughout the present inquiry, reserving its theory or explanation to the present time.

Advantage is frequently taken of the strong chemical affinity between salt and frozen water, for removing hard-trodden snow from foot pavements, the salt is merely sifted or sprinkled on its surface, and liquefaction ensues in the course of a few minutes ; the brine is then swept away, and the pavement effectually cleansed, it is true, but likewise cooled to zero, and therefore chills the incumbent air much below its ordinary winter temperature.

If we have been walking along the streets for some distance upon snow, the feet become inured to its temperature ; but coming suddenly upon pavement recently cleansed from it by salt, its intensity of cold in comparison with that we have quitted, becomes painfully sensible to the feet, especially if clad in thin soled shoes.

Confectioners, by employing a mixture of ice and salt, are enabled to obtain a low temperature even in the height of summer, to produce various ices for the table; the salt may be recovered in a solid form by the evaporation of the brine, and may be employed again and again for the same purpose, because it sustains no change in its chemical constitution.

A very simple, yet extremely instructive experiment regarding the intense cold of a freezing mixture, may be performed at any season of the year, and even in front of a blazing fire, as follows: pour a large spoonful of water upon the middle of a wooden trencher; place the polished tin canister that was employed in a former experiment, page 206, to stand in this little pool, then fill the canister with a freezing mixture, adjust its cover, and insert the thermometer through its aperture.

In the course of a few seconds, the polish of the canister will become dim with moisture, because the warm air, containing aqueous vapour, wafting around its cold surface, is reduced to the dew point and compelled to deposit dew, but the cold is more than sufficient to effect this—the thermometer indicates 0° —and accordingly, in the lapse of a few more seconds, a kind of white smoke will surround the canister; this consists of myriads of minute crystals of hoar-frost, into which the dew is compelled to change—it is exactly analogous to the frost smoke, page 336—and in the course of some minutes will thickly encrust the outside of the canister, which simultaneously acts as the means of their formation and the nucleus for their support, and likewise for reducing to 32° the temperature of the little pool of water in which it was originally placed; so that now, taking hold of the knob of the cover and lifting it, the canister will be found frozen to the trencher.

The heat that is rendered latent during the liquefaction of ice and other solids, remains in the resulting liquids, and is again rendered sensible during their congelation.

Expose a vessel of warm water to a very cold atmosphere, the temperature of the water will rapidly sink to 32° , and then it will slowly congeal; if kept in the same situation, heat is of course abstracted as before, but the thermometric indication remains stationary at 32° , until the whole be frozen, after which the temperature of the ice will sink to that of the surrounding atmosphere.

When the temperature of the air is 22° , if we expose to it one vessel filled with water, and another filled with brine, at the same temperature, and a thermometer in each liquid, we shall find that they both lose heat, and are cooled to 32° .

After this, the brine—which does not freeze until cooled to 4° —continues to cool without interruption, and gradually attains 22° , the temperature of the air; but the water remains stationary at 32° , it freezes indeed, but very slowly, and during the whole process its temperature is 32° .

The water as it freezes, gradually gives out the heat which it had absorbed during its liquefaction, and this evolution maintains the temperature of the water at 32° , notwithstanding what it parts with to the air during the whole process.

It is easily shown that water while congealing is constantly imparting heat to the surrounding air; for a very delicate thermometer suspended above its surface is affected by an ascending current of air of greater temperature than that around.

Chemistry adduces this fact as another example of a miraculous provision that is beneficently made by the Creator for mitigating the rigour of winter, by ordaining that water during its congelation should yield up its stores of latent heat to the ambient air, and thus gradually reconcile animated beings to this wondrous and important physical change; the latent heat would be useless if it remained in the water, it is therefore liberated by the Hand of Providence where its presence is needed for the welfare of the animated creation.

Latent heat present in a liquid, and insensible to the thermometer, becomes sensible if the liquid be caused to assume the solid state, as may be shown by the following experiment, which can be made at any season. Add crystals of sulphate of soda to a pint of boiling water, until a considerable portion remain undissolved; and thus obtain a hot saturated solution, filter it through a piece of fine muslin, into a perfectly clean finger-glass until it be nearly filled; place the finger-glass, containing the solution, upon the mantelshelf that it may not be shaken, as it would be if set on the table by the vibration of the floor; close the doors and windows of the apartment that the surface of the solution may not be ruffled, nor become dusty, in fact take every precaution to keep the glass steady, and the solution clean.

In the course of a few hours the solution will have cooled to the temperature of the apartment, and, generally speaking, without depositing crystals; or, in other words, the crystallization of the sulphate of soda is suspended, as that of water may sometimes be, when kept unruffled and reduced to a low temperature.

Note the temperature of the air, then gently plunge the bulb of the thermometer into the solution, very probably crystals will instantaneously accrete around it as a nucleus, and then gradually extend therefrom, until the whole contents of the finger-glass assume the form of one solid crystalline mass; if this happen, the thermometer will indicate a very considerable increase of temperature, and indeed this will be immediately detected by the hand upon grasping the outside of the finger glass.

The heat becomes sensible, because the sulphate of soda cannot assume the crystalline form, unless it combine with fifty per cent. of water, and during this sudden transition from one state to another; the latent heat that existed to maintain the liquid, is now expelled or rendered sensible, as it is not needed to maintain the solid form.

The crystals of sulphate of soda that were originally dissolved to form the solution, contained nearly the same percentage of water as those now deposited, although they might have felt perfectly dry to the touch, but exposed to the air for a few hours, their surfaces, instead of remaining transparent and glass-like, would have become opaque and pulverulent, and so will the newly-formed crystals become if removed from the finger-glass to a sieve and allowed to drain.

In the language of Chemistry, the water thus solidified or combined with crystals, is called water of crystallization and in the case before us, it is not combined with a very strong degree of affinity; so that upon exposure of the crystals of the atmosphere, a portion dries from them, they become opaque and pulverulent, and are technically said to effloresce.

The crystals may be preserved in their original transparency by placing them in a confined volume of air saturated with aqueous vapour, page 76, and thus the chemist manages to keep specimens of most of the efflorescent salts; such as attract water from the atmosphere, as pearlash, or are deliquescent salts, he keeps in accurately stoppered bottles, and such as neither give out nor attract water—as nitre—or are permanent salts—he keeps in common bottles and boxes.

The suspended crystallization of sulphate of soda is rather uncertain; sometimes crystals will form as the solution cools, at others upon touching it with the thermometer; at others again it will not crystallize unless briskly stirred with the bulb, often the merest agitation of the air will determine the formation of crystals, and as often it will fail to do so, but the phenomenon if it do not occur by any of the above means, will invariably and immediately happen when a minute crystal of sulphate of soda is dropped into the solution.

No satisfactory explanation has been offered regarding

the cause of this suspended crystallization ; it is, however, not a solitary instance, for six or seven other solutions of salts are known to present the same phenomenon ; the sulphate of soda has been chosen on account of its abundance and cheapness, the crystals may be re-dissolved and employed again and again.

Returning more immediately to the congelation of water, it must be remarked that ice will not form at any temperature above 32° , but once formed, its temperature may then be reduced by natural or artificial means even below the freezing point of mercury— 52° below 0° —this fact is often neglected, but it should be borne in mind, or the student of Chemistry would run into serious error by supposing that every lump of ice, hail-stone, snow-flake, or crystal of hoar-frost, has only a temperature of 32° ; true that such temperature of 32° , and no other, is absolutely necessary for the production of these physical forms of water, but they are all subject to its subsequent reduction to a lower degree by the continued cold of winter, or by artificial sources of cold.

Inattention to this fact would render the graduation of a thermometer useless ; if the bulb of the newly-formed instrument were simply plunged amidst powdered ice or snow, and the point to which its mercury contracted by such cold were marked upon the tube as the freezing point of water, the temperature of the ice or snow might be zero, or even many degrees below, so that the instrument, if subsequently plunged into boiling water, for obtaining the other point, and the space between the two then divided into 180° , it would be false in its construction, and could never indicate with truth either the freezing point, or the boiling point of water, or any other intermediate temperature.

But the experienced chemist discovers that the freezing point of water is actually the melting point of ice, and that so long as a particle of ice remain, the water produced by the thawing of previous portions will maintain the temperature of 32° , page 398 ; he therefore allows a mass of ice to

thaw, and places the bulb of the thermometer in the resulting water, full confident of obtaining the true freezing point, and then subsequently proceeds with the graduation of the scale.

As the great amount of heat required for the liquefaction of ice and snow is withdrawn from the atmosphere, its temperature is very considerably reduced, and hence the popular expression of "a cold thaw," is explained upon philosophical principles. Ice to become liquid water, renders latent 140° of heat, but this water to become steam at 212° , renders latent heat no less than 960° , or more probably 1000° of heat, it matters not how fierce may be the fire, or how vehement the boiling of the water in an open vessel, its temperature and that of its steam will never exceed 212° , so long as the barometer indicates 30 inches as the atmospheric pressure; the excess of heat from the fire is rendered latent in the steam, and insensible to the thermometer.

When steam having a thermometric temperature of 212° impinges upon a cold surface, and condenses thereby into liquid water, it relinquishes its latent heat which then becomes sensible to the thermometer.

Thus in the process of distillation, the steam at 212° coming into contact with the upper part of the cold worm-pipe is condensed, and its latent heat, being received by the surrounding cold water, this becomes elevated in temperature; it may also be observed, that such heated water will float upon the colder portion below for a considerable time—as it is a bad conductor—if the distillation be protracted, the whole of the water in the worm-tub will acquire the temperature of the steam, and will of course be unable to condense it any longer, so that a volume of steam will freely issue from the lower end of the worm-pipe, instead of the liquid drops as at the outset of the process, when the water was cold.

It is on account of steam thus containing such an enor-

mous store of latent heat, that its power of scalding the body is so great; for whenever steam comes into contact with a surface colder than itself, it condenses, and its latent heat becomes sensible.

When a fog occurs during autumn or winter, the well known increase in the temperature of the atmosphere is referrible to the latent heat that existed in the watery vapour, becoming sensible during its condensation or change to the liquid state; and if wind subsequently occur it is accompanied by decrease of temperature, because heat is absorbed or rendered latent by the water for its evaporation, or change into the state of vapour.

Thick and substantial walls of the interior of houses become damp, and often very wet, in certain states and changes of weather; they are so massive as to retain an acquired temperature for a considerable time, and during a frost become cooled throughout; then upon a sudden thaw, attended by a very humid state of the atmosphere, the vapour or moisture of the air is condensed into the liquid state upon these cold surfaces, because they abstract its heat and cause it to run down as water.

Chemistry discloses a most extraordinary fact regarding the vapour of water, namely, whatever may be the temperature of the vapour, it invariably contains the same quantity of heat.

The details of this discovery cannot be given in this general inquiry, but a few examples of the fact may be presented; these, when accurately and minutely considered, display much to excite our admiration and astonishment regarding the habitudes of water with heat, and the important part enacted by such compound in all its physical states throughout the four seasons.

A certain weight of steam, at 212° , if condensed at 32° , gives out 180° of its original sensible heat, and 950° of latent heat, so that the whole amount of heat contained in the steam is equal to 1130° ; the same weight of steam at 250°

similarly condensed at 32° , gives out 218° of sensible heat, and 912° of latent heat, so that the whole amount of heat contained in the steam is again equal to 1130° ; the same weight of steam at 100° , similarly condensed at 32° , gives out 68° of sensible heat and 1062° of latent heat; so that the whole amount of heat contained in the steam—as in the two first instances—is equal to the constant number of 1130 degrees.

Upon these incontrovertible facts a law is established to the effect, that in proportion as the thermometric or sensible heat of steam is increased, so is its latent or insensible heat decreased; and in proportion as its sensible heat is decreased, so its latent heat is increased.

Chemistry applies the results of these experiments to the explanation of natural phenomena, and leads to the conclusion that similar weights of the vapour of water produced by the different temperatures of spring, summer, autumn, and winter, contain a similar and a constant amount of heat; and without this imponderable agent so miraculously treasured by the Almighty in the vapours and floods, the air and the earth, the animated Creation would cease to be.

Let us now remark and appreciate the beneficial results which ensue throughout the Creation by the operation of the immutable laws that we have been considering and endeavouring to illustrate by experiment.

The ice, snow, and frost of winter, do not suddenly change into floods upon the first accession of the heat of spring; did they so change, the earth and its productions would be immediately inundated by the emancipated waters.

On the contrary, the Hand of Infinite Wisdom ordains that each mass of ice, flake of snow, and pearl of frost, shall slowly absorb, and render latent a definite amount of heat, and thus gradually change into a salutary stream instead of abruptly changing into a destructive torrent.

When the imprisoned waters are emancipated, or unbound by the genial warmth of spring, and exposed to the heat of

summer and the glow of autumn, they display the same beneficence of the Creator in the adjustment of their temperature to the peculiar organization of animal and vegetable productions, as they manifested during the cold of winter.

In spring, summer, and the early part of autumn, warm winds glide over the liquid surface of the fresh-water lake chosen as our example for explaining the phenomenon of congelation; its surface water gains heat by the contact, becomes lighter, and then floats upon the colder water beneath, the temperature of the surface may be 62° , whilst that of the depth may remain at 40° ; no sudden elevation of temperature can ensue throughout the whole bulk, as it has no conducting power, and the fishes become gradually inured to the elevation of temperature that is ultimately established throughout the water by the mechanical agitation of the spring, summer, and autumn winds.

CONCLUSION.

IN approaching the conclusion of this inquiry regarding several phenomena of the Four Seasons, which admit of interpretation by the science of Chemistry, it becomes necessary to present a statement of the magnitude of the earth, and the size of man; for we shall then marvel at the beneficence of the Creator in permitting such phenomena to be interpreted and understood by His creatures.

The earth is eight thousand miles in diameter from pole to pole; the atmosphere is calculated to be fifty miles in altitude, page 21; the loftiest mountain—inaccessible—is estimated to be five miles above the level of the sea; the deepest mine therefrom is five hundred and fifty yards, and the stature of man does not average six feet.

Were it possible for man to construct a globe eight hundred feet in diameter—twice the height of St. Paul's cathedral—and to place upon any part of its surface a particle of matter the ~~hath~~ th part of an inch in height, such particle, undiscoverable by the naked eye, would nevertheless correctly denote the proportion that his body bears to the earth upon which he stands.

If he would condescend to bear in mind the fact of his own insignificance, and the magnitude of his dwelling-place, and humbly acknowledge himself to be a mere atom of dust in the stupendous scale of the Creation, it would act as a salutary check to the pride of his half knowledge, which too frequently induces him to pronounce dogmas regarding the causes that "*must be operating to produce changes*" above and below the surface of the earth, because he finds such and such phenomena presented to his finite comprehension, after laboriously climbing upon a natural hillock, or painfully creeping within an artificial burrow.

How magnificent is the language of Scripture when extolling the omnipotence of God, and alluding to the insignificance of man!

"It is He that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers; that stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in."

"Behold the nations are as a drop of a bucket, and counted as the small dust of the balance: behold He taketh up the isles as a very little thing."

"All men are earth and ashes: then shall the dust return to the earth as it was: and the spirit shall return unto God who gave it."

"As for the wondrous works of the Lord, there may nothing be taken from them: neither may anything be put into them: neither can the ground of them be found out."

"When a man hath done, then he beginneth: and when he leaveth off, then he shall be doubtful."

"He shall be confounded or amazed to find when he leaves off how many of the works of God he hath omitted."

Upon due reflection concerning these, and other equally sublime descriptions of the majesty of God, and the wisdom and magnificence of His works, we are led to exclaim with the Psalmist :—

" Lord, what is man that thou art mindful of him, or the son of man that thou regardest him ?"

Yet has the Almighty, " the Father of lights, in whom is no variableness neither shadow of turning " in His abundant goodness vouchsafed to man " certain knowledge of the things that are, namely, to know how the world was made, and the operation of the elements."

" The beginning, ending, and the midst of the times : the alterations of the turnings of the sun and the change of seasons."

From the spring, when all vegetation is bursting into life, to the summer, when glowing with beauty and sweetness, to the autumn, when teeming with all the purposes for which this vitality and perfection were called into being, and finally to the winter, when it is shrouded in sleep and repose.

We have seen that everything is " beautiful in its season," that " all the works of the Lord are good ; and He will give every needful thing in due season."

" So that a man cannot say, this is worse than that, for in time they shall all be well approved."

" Wisdom is the breath of the power of God, and a pure influence flowing from the glory of the Almighty," and concerning the wondrous phenomena of the Creation, it is acquired by man through the proper and chastened exercise of his noblest faculties, and thus a grateful appreciation of the beneficence of God, completely harmonizes with an implicit faith in his Revealed Will.

Unless a firm belief of another, and higher state of existence dwell within the mind of man to uphold him during

the period of his sojourn upon earth, his science is vain, his philosophy is false.

As intricate derangements of the elements of nutritious food, cause its transition into deadly compounds by the refined experiments of the chemist; so do subtle perversions of the elementary truths of pure science yield moral poisons by the cunning of the sophist; but the first shrinks back with fear and dread lest his discovery should be wilfully or accidentally misapplied, whilst the second stands forth with presumption and arrogance, and vaunts upon the exhibition of his morbid skill in turning good gifts to bad purposes.

It accordingly behoves the teacher of experimental science, to "put on the whole armour of God; to stand girt about with truth," and thus not only instruct the young disciple regarding natural phenomena, but guard his mind by the Divine admonitions which irradiate the invincible "shield of Faith wherewith he shall be able to quench all the fiery darts of the wicked;"—

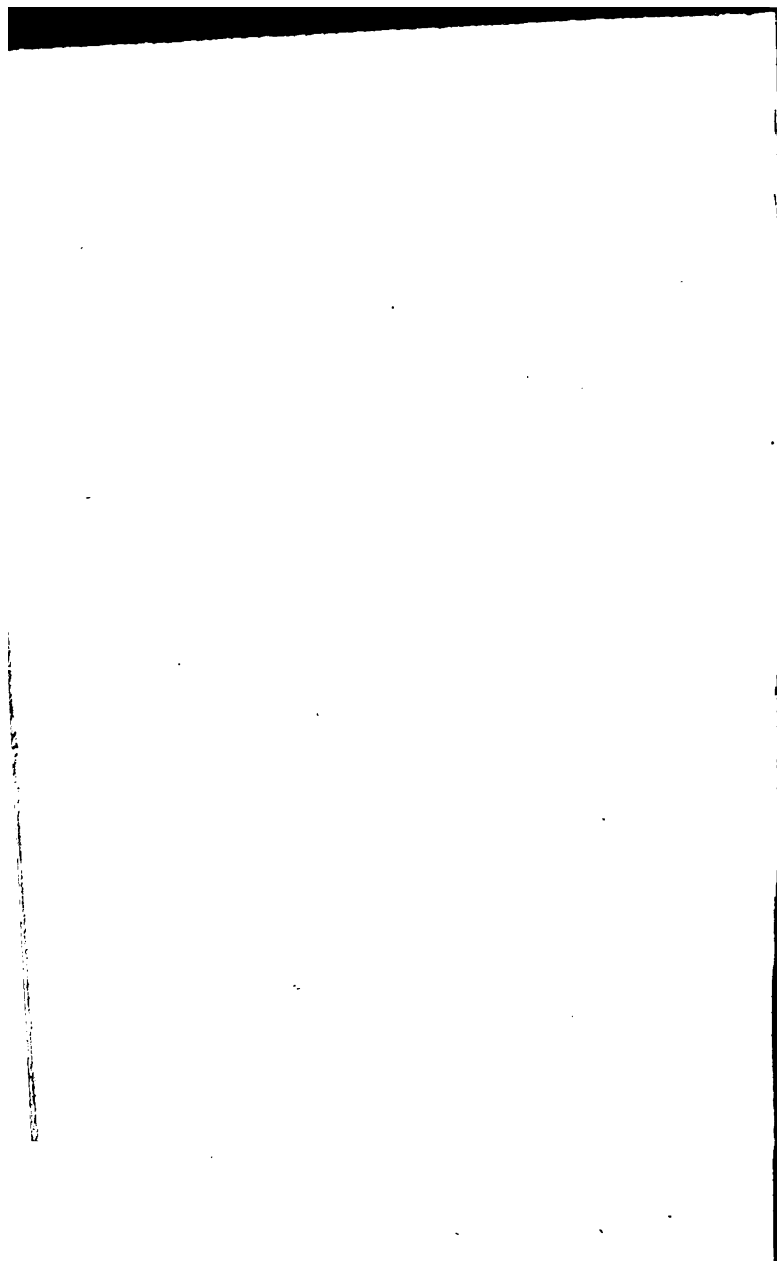
"Prove all things; hold fast that which is good."

"Be not carried about with divers and strange doctrines."

"Perverse disputings of men of corrupt minds, and destitute of the truth, supposing that gain is godliness, from such withdraw thyself."

"And this I say, lest any man should beguile you with enticing words."

Whilst it shall please the Almighty to continue us in this world where so much is to be done, and so little to be known, we must employ the talents intrusted to our care, with unremitting zeal and humble confidence, and wait with patient expectation for the time in which the soul, returning to the bosom of its God, "shall be satisfied with knowledge."



APPENDIX,

CONTAINING

The Names of the Discoverers, Historians, Narrators, and Exhibitors of the principal Facts which are embodied in this Work.

ALLEN and PEPYS ascertained the quantity of carbonic acid exhaled by a healthy adult in twenty-four hours; they also made important experiments regarding Priestley's discovery of the renovation of vitiated air by plants.

BACON, LORD, must be considered as the founder of Inductive Philosophy, real knowledge being, in his view, "not a couch whereupon to rest a searching and restless spirit; or a terrace for a wandering and variable mind to walk up and down with a fair prospect; or a tower of state for a proud mind to raise itself upon; or a fort, or commanding ground of strife and contention; or a shop for profit and sale, but a rich store-house for the glory of the Creator, and the relief of man's estate."

BALARD discovered bromine.

BALDWIN made several interesting experiments upon phosphorescent substances.

BANKS, SIR J., remarked the fact of the sun-burn on the back of a liver-fish when exposed to the sunshine after the trees were felled round the pond.

BERARD accurately examined the changes sustained by the atmosphere during the ripening and decay of fruits.

BERGMAN introduced methods of analysing waters from various natural sources.

BERZELIUS discovered selenium, thorium zirconium, and first obtained pure silicium or silicon.

BLACK, DR., discovered chalk to consist of carbonic acid and lime; proved the thermometer to afford no correct indication regarding the absolute quantity of heat required to produce a given temperature, or, in other words, ascertained the capacity of bodies for heat; he discovered the amount of heat which becomes latent during the thawing of ice and the liquefaction of other solids, he also discovered the latent heat of steam.

BOYLE, HON. ROBERT, corroborated the original experiment made by Van Helmont with the willow tree; improved the air-pump and rendered it an available apparatus for philosophical research; made the first accurate researches concerning the rarefaction and condensation of air; recorded the fact of vegetable aroma being retained by the air with persistent force, and travelling with it many miles to seaward; introduced the form of the air thermometer as shown at page 145; "turned his attention with much earnestness to the construction of a scale for thermometers, and seems to have had it in contemplation to set out with the temperature at which water begins to freeze;" but he did not pursue this inquiry, fearing that many objections would be raised against its practice.

BRANDE made numerous and highly important experiments regarding the chemistry of organic bodies; made the first accurate experiments, upon a large scale, concerning the produce, purification, and illuminating power of gas from coal.

BRANDT discovered phosphorus, and first pointed out the characters of arsenicum.

BRAUN discovered that mercury might be frozen by a low degree of artificial cold.

CALLIMACHUS is said to have first observed the beautiful form of an acanthus diverted from its original position of growth, and thence to have invented the Corinthian capital.

CANTON made many experiments upon phosphorescent substances.

CAVENDISH, HON. H., demonstrated the composition of nitric acid, and its formation by the passage of electricity through atmospheric air;

discovered the composition of salt-petre; discovered the composition of water; first accurately examined the properties of hydrogen.

CHRISTISON investigated the action of poisons upon plants.

CLAYTON discovered that inflammable gas might be obtained by the distillation of coal.

COURTOIS discovered iodine.

CRAWFORD made numerous experiments upon the capacity of bodies for heat.

CROUNE was probably the first to discover that water expanded when cooled to a certain degree; but the Florentine academicians accurately examined the remarkable phenomenon.

CULLEN discovered that cold was produced by the evaporation of ether and alcohol at common temperatures.

DALTON investigated many of the phenomena concerning the evaporation of water, and the definite weights in which elements and compounds combine.

DANIELL ascertained the rate of the evaporation of water during different states of the atmosphere; invented the only accurate hygrometer; brought the barometer to its present state of excellence.

DARCEY discovered that the diamond was combustible.

DAVY, SIR H., discovered barium, boron, calcium, lithium, magnesium, potassium, sodium, and strontium; demonstrated the composition of rock-salt, and that lime, sand, clay, magnesia, potassa, and soda, were oxides of metals; suggested the nature of fluorine, and proved that of chlorine; first devised methods of analysing soils; discovered that soils differ in their absorption and retention of heat; pointed out the doctrine of the proper application of manures; ascertained the composition of the gas emitted from the mud of stagnant waters; discovered silica as the coating or clothing of grasses, and melted a wheat-straw into a globule of glass by intense heat; explained the philosophy of the old proverb regarding the morning and evening rainbow; discovered the existence of water in crystals and pebbles of silica; discovered the composition of the fire-damp of coal-mines, investigated the phenomena of combustion, and crowned his unrivalled researches by the invention of the safety-lamp for coal miners, who have named it "the Davy," in honour of its philanthropic discoverer and donor.

DREBBEL and SANTORIO appear to have an equal claim to the merit of the discovery of the thermometer.

FARADAY corroborated the fact discovered by Cavendish, of the formation of nitric acid by the action of electricity upon atmospheric air; demonstrated that chlorine, hydrochloric acid, nitrous oxide, carbonic acid, ammonia, and some other æriform substances that were formerly thought to be permanent gases, rather merited the title of vapours, as they condense into liquids by pressure and cold, and some even congeal into solids by the lowest reduction of temperature that can be obtained.

FLORENTINE ACADEMICIANS (the) constructed the first instrument to which the term "thermometer" can properly be applied; it closely resembled the arrangement represented at page 142.

FORBES ascertained the probable physical cause of the red colour of the morning and evening sky.

FRANKLIN first conducted lightning from the clouds, and proved its identity with electricity artificially excited; he also proposed the attachment of conductors to buildings; and probably first made the experiment with the nine pieces of cloth placed upon snow exposed to sunshine.

GAHN and SCHEEL discovered the composition of bone-ash, and obtained phosphorus therefrom.

GALILEO first suspected that the atmosphere was a ponderable substance, and invented a syringe or pump for the compression of air.

GALVANI and VOLTA engaged in a controversy regarding muscular motion; and one of the consequences of their difference of opinion was the discovery of the intimate relation between chemistry and electricity.

GAY LUSSAC discovered hyponitrous acid; and proposed the form of the lightning conductor, or "paratonnere," page 198; discovered the definite law of combining volumes of gases and vapours.

GEBBER, in the seventh century, first made the substance called "red-precipitate," from which oxygen gas was educed by Priestley, in 1774.

GEOFFROY constructed the first tabular forms for expressing the force of chemical affinity.

GLAUBER discovered that vinegar might be obtained by distilling wood at a red heat; gave the first directions for obtaining "spirit of salt"—hydrochloric acid—and also "sal mirabile"—sulphate of soda. "He was a most industrious man, cast in the true mould of an experimental chemist."

GRAHAM accurately determined the expansibility of liquids by heat.

GRIFFITHS made many experiments on the eduction and properties of charcoal from various dense woods. Ascertained the boiling-points of numerous saturated solutions of saline substances. Determined the hygroscopic powers of an extensive class of insoluble bodies. Invented several arrangements for demonstrating the conduction of heat by solids; its non-conduction and convection by liquids; and announced the probable physical cause of the instantaneous expansion of a volume of non-conducting air by the agency of heat. Discovered the action of water upon glass; experimented upon the deposition of crystals being affected by the smooth or rugged nature of nuclei. Invented the method of obtaining phosphorus in a comminuted state for the manufacture of lucifers. Discovered the floatation of saline solutions upon each other; but the arrangement for the exhibition of the fact, as described at page 322, was perfected by his valued friend and assistant the late T. S. Dick.

GUERICKE, OTTO, first publicly demonstrated the enormous pressure of the atmosphere upon the exterior of an exhausted vessel; invented the air-pump, and also the useful meteorological toy now so familiarly known as "the weather-house."

HALES experimented upon the motion of sap in plants, and their power of transpiring watery vapour; invented the revolving ventilators that are commonly used for allowing heated and vitiated air to escape from rooms.

HALLEY is regarded by many writers as entitled to the merit of fixing upon the boiling-point of water as a standard for the graduation of the scale of the mercurial thermometer.

HANCKWITZ first obtained phosphorus upon a large scale, and sold it as a chemical curiosity at the rate of one hundred shillings per ounce.

HATCHETT made the first accurate experiments concerning the hardening principle of shell, coral, and bone.

HIGGINS has the exclusive merit of laying the foundation of the theory of definite proportions; for the essential facts, which have been subsequently followed up, and worked out by later chemists, are to be found in his works, dated 1789.

HUME, Sir E., made the experiments regarding the absorption of heat by the skin of the Ethiopian.

HOOKER is generally thought to have discovered the two fixed points for the graduation of the scale of the thermometer; he also shrewdly suspected nitre to contain a principle identical with that in the atmosphere which supports combustion; this was subsequently proved to be a fact by Priestley, Lavoisier, and others.

INGENHOUSZ ascertained the relative conducting power of the metals regarding heat, and devised experiments for illustrating the difference between conductors and non-conductors of heat.

IRVINE experimented regarding the capacity of bodies for heat.

KING described the snow-houses of the Esquimaux.

KUNKEL made several experiments upon phosphorescent substances.

LABARRAQUE proved the great power of chlorinated lime and chlorinated soda, as preventives of putrefaction and as disinfectants.

LAPLACE made a series of important experiments upon the capacity of bodies for heat.

LAVOISIER discovered the composition of gypsum—sulphate of lime—and demonstrated the atmosphere to be chiefly a mixture of oxygen and nitrogen gases.

LESLIE discovered that water might be frozen by the cold produced during its own evaporation; he also made the first accurate experiments upon radiant heat, as regards the manner in which its reception and retention may be affected by surfaces.

MACBRIDE suspected the presence of carbonic acid in the atmosphere, and discovered that vegetable and animal substances produced carbonic acid during their fermentation and putrefaction.

MACOULLOCH made valuable observations regarding malaria.

MAROT examined sea-water from various parts of the world.

MAYOW discovered that bodies increased in weight during combustion, and referred the phenomenon to their "fixation"—combination with—"of nitro-aërial particles"—oxygen—from the atmosphere.

MORVEAU first proved that hydrochloric acid and chlorine vapours might be used as disinfectants.

NEWTON, Sir I., by his sagacious views regarding mechanical and chemical attraction, destroyed the ancient notions that the particles of bodies were held together by hooks, rings, points, and wedges. He says, "I use the word attraction to signify any force by which bodies tend towards one another, whatever may be the cause;" explained the physical cause of the rainbow, and analysed light by a prism of glass; hinted that diamond and water contained inflammable matter

—carbon and hydrogen—and suggested that the melting-point of ice should be taken as the commencement of the graduation of the thermometric scale; but Hooke made the discovery that in melting ice, and in boiling water, the mercury of a thermometer always contracted and expanded to certain points.

NICHOLSON and CARLISLE made the important discovery of the decomposition of water by electricity, and the simultaneous eduction of its element, oxygen and hydrogen; this has never yet been effected by any other agent.

PASCAL proved the atmosphere to decrease in density in proportion to its altitude; and he proposed the employment of the barometer as a "weather-glass."

PRIESTLEY, Dr., discovered that heated "red precipitate" evolved æriform matter; this he imagined to be air, deprived of some combustible matter; he therefore named it "dephlogisticated air;" the French chemists subsequently found that it produced acids, and, therefore, named it oxygen. Priestley discovered the evolution of oxygen by aquatic plants when growing in water containing carbonic acid; that the presence of light was necessary for this phenomenon to ensue, and that it was, in a great measure, independent of heat; he discovered the purification of air by growing plants, page 128, and was addressed regarding it, page 130, by Sir J. Pringle, President of the Royal Society.

REY discovered that some metals heated in air, tarnished and increased in weight, and suspected that this phenomenon depended upon the fixation by the metals of some principle of the atmosphere; this suspicion was confirmed upon the discovery of oxygen by Priestley.

ROEMER and BRADLEY calculated the velocity of light.

RUMFORD, Count, made several interesting and important discoveries and experiments upon the radiation and conduction of heat, and the construction of fire-places.

RUTHERFORD, Dr., first examined pure nitrogen.

SAUSSURE discovered the form of vesicular vapour in alpine mists.

SCHÉELE discovered chlorine; ascertained that atmospheric air was a mixture of two gases, one of which was capable of supporting combustion; this he named, "empyrean air;" the other, incapable of supporting combustion, this he named, "foul air;" these are the oxygen and nitrogen of modern chemistry; he demonstrated silica

and alumina to be distinct substances ; discovered means of producing soda from common salt ; "first noticed the distinction between heated air and air emanating from a heated body in straight lines ;" or, in modern terms, the difference between aerial convective currents and radiation of heat. He says, "represent to yourself a little hillock of burning coals ; in this case the heat darting from this hillock all around, is that which may be reflected by a polished plate ; that, on the contrary, which rises upwards and may be driven by the winds to and fro, unites with air. I call the first kind, by way of distinction, radiant heat."

SCHRAEDER analysed the seeds of wheat, rye, barley, and oats, and ascertained the quantity of earthy matter which each contained ; he also made elaborate experiments upon the absorption or secretion of such matter by growing plants.

SEGUIN experimented upon the transpiration of moisture from the human body.

SINGER gave the best directions for ensuring personal safety during a thunder-storm.

SMEATON brought the air-pump to its present state of perfection.

SMITH proved the invaluable property of nitric acid vapour as a disinfectant.

SMITHSON ascertained the form of hailstones and snow-flakes.

TENNANT made many useful applications of chemistry to agriculture ; he probably discovered, certainly first made, chloride of lime, or chlorinated lime, under the name of oxymuriate of lime, as a bleaching material.

TORRICELLI invented the barometer.

VAN HELMONT first employed the term "gas ;" he made the remarkable experiment concerning the growth of the willow-tree in a limited quantity of earth, watered for several years with nearly pure or distilled water.

WARD discovered that plants would grow and flourish in a confined portion of air.

WARRINGTON lately examined the conditions under which fishes may be preserved in a healthy state, when placed in water contained in glass globes or other artificial receptacles, with growing plants, and recommended the following arrangement : at the bottom of a large glass globe, place clean gravel to the depth of about an inch ; on this place, grotto fashion, several pieces of sandstone and

limestone rock, so that the fishes to be subsequently introduced can shelter below them; plant in the gravel two or three roots of the *Vallisneria spiralis*; fill the globe to about one half its contents with ordinary spring water, introduce the fishes and five or six water-snails—the *Limnea stagnalis*; lastly, cover the mouth of the glass globe with a piece of thin muslin strained over a hoop to prevent the admission of dust, but to permit the admission of air. The following actions then commence and continue:—carbonic acid is produced by the fishes; is decomposed by the plant; the snails feed and thrive upon its decaying matter, and deposit gelatinous masses of eggs; these when they evidence vitality are devoured by the fishes; the plant derives nourishment from the exuvise, grows rapidly, and puts forth blossoms on the surface of the water; the fishes remain lively, bright, and healthy, and may thus be kept for two or three years without change of water.

WATT proposed chlorine as a bleaching agent; and probably first observed that moisture was deposited upon a cold surface when held over the flame of inflammable air—hydrogen—he made the first capital improvements on the steam-engine.

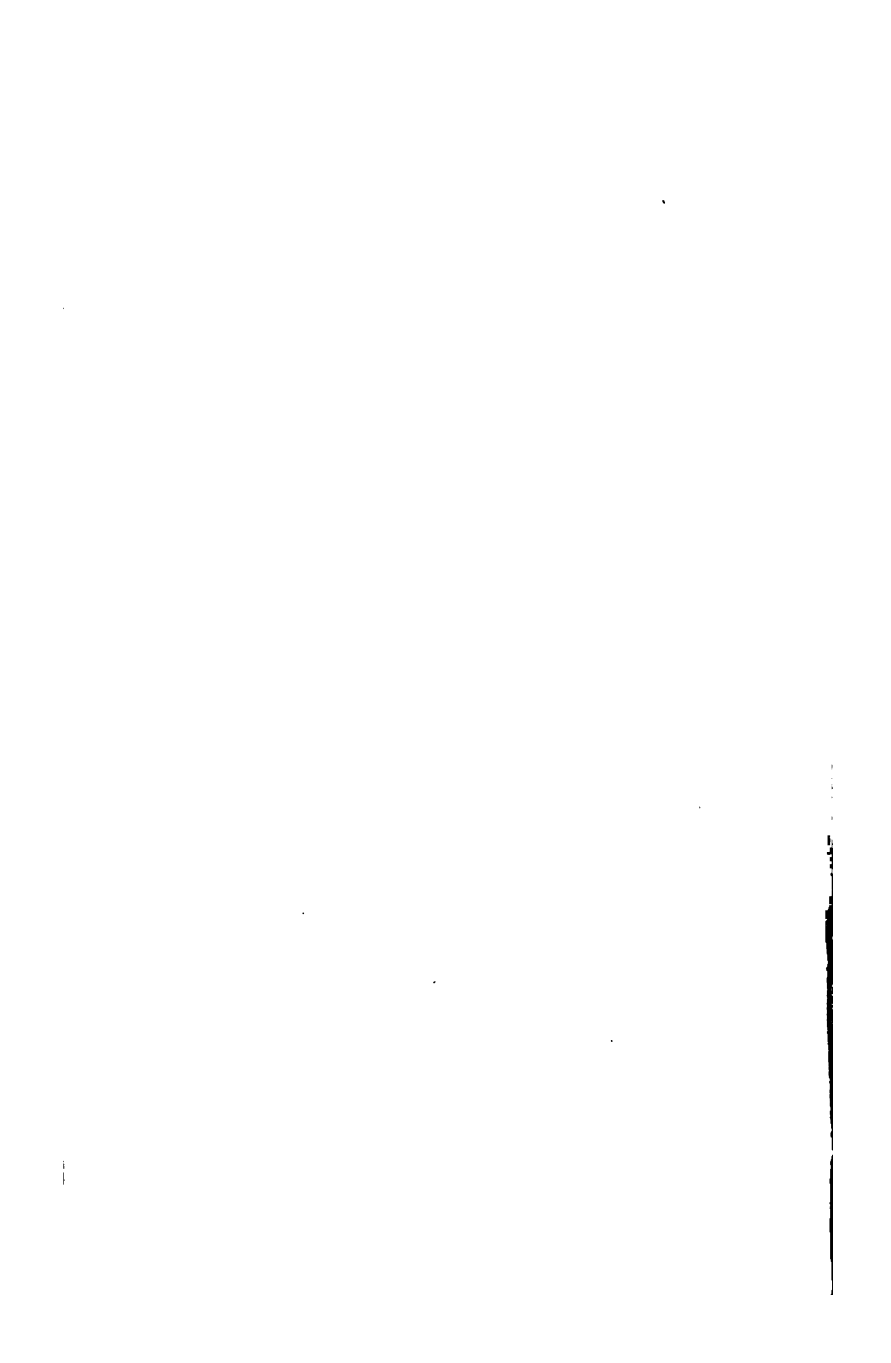
WELLS, Dr., discovered the physical cause of the phenomenon of dew.

WILLIAMS made the experiments upon the rupture of iron bomb-shells when the water contained in them was frozen.

WOHLER accurately demonstrated the nature of alumina.

WOLLASTON, Dr., invented the cryophorus.

WOODWARD experimented upon the transpiration of water by plants.



INDEX.

- Absorbers of heat, 54
 Absorption of water by seeds,
 soils, 61
 Acacia vera, 275
 Acanthus diverted from its natural
 growth, 115
 Acetic acid, 284
 Acid vapours injure plants, 150
 Aëration of water, 235
 Aërial moisture attracted by soils, 75
 Air-pump construction, and the use
 of the, 165
 Albumen, 43, 46
 Alcohol, 276
 floatation of, on water, 318
 mixture of, with water
 evolves heat, 163
 specific gravity of, 315
 Alphabetical list of elements, 4
 Altitude of the atmosphere, 21
 Alumina, or pure clay, 36
 Aluminum, the metal of alumina or
 clay, 34
 Ammonia, 33, 274
 Analysis, examples of, 68
 Ancient elements, 14
 Andes, climate of the, 171
 Anhydrous, definition of the term,
 20
 Animal bodies, elements of, 44
 functions influenced by light,
 140
 Animals, clothing of, 397
 Animated kingdoms, mutual de-
 pendence of the, 51
 Annuals, 120
 Antiseptic power of ice, 328
 Apparatus required in chemistry, 1
 Apartments fumigated, 260
 ventilated, 387
 warmed, 386
 April showers, 72
 Aquatic plants decompose carbonic
 acid, 239, 243
 Aqueous vapour, 423
 absorption and
 transpiration of, by plants, 118, 119
 detected in air, 180
 Arctic circle, water of the, 309
 regions, intense cold of the,
 365
 Aroma of flowers, 263
 Artificial ice, 402
 Ashes of vegetables, 282
 weight of, from wheat and
 other straw, 188
 Atmospheric air, 15
 affected by lightning,
 17
 altered in nature by
 combustion, 81
 by germination, 86
 by respiration, 83
 analysed, 15, 18, 88
 aqueous vapour of
 detected, 180
 assumed as a stan-
 dard of unity, 23
 blue and other co-
 lours of, 99
 carbonic acid at-
 tracted from by lime, 133
 deduced
 from, 130—138

- Atmospheric air, condensation of,**
 evolves heat, 164
 contains ammonia, 33
 carbonic acid, 18
 nitrogen, 15
 oxygen, 15
 watery vapour, 18, 180
 density of, diminishes in proportion to altitude, 170
 deposition of dew from, 216
 expansion of, by heat, 78, 367
 growth of plants in a confined portion of, 152
 hydration of, necessary for animal and vegetable life, 284
 incapable of being heated by the solar rays, 55
 mean pressure and temperature of, 23
 mercury supported by, 22
 non-conducting power of, 366
 poisonous exhalations in, 150
 pressure of, upon a square inch, 23
 probable extent of, around the earth, 21
 processes for the analysis of, 88
 purification of, by growing plants, 126
 saturation of, with aqueous vapour, 78
 specific gravity of, 23
 synthesis of, 95
 total weight of, 21
 tranquillity of, essential to the deposition of dew, 216
 ultimate elements of, 20, 42
 unaltered in nature by heat or cold, 78
 vegetables secrete carbon from, 124
 volumes of its oxygen and nitrogen, 91
- Atmospheric air, weight of a cubic foot of, 288**
 around the earth, 21
 yields carbon to vegetation, 123
Atmospheric dryness, 232
Autumn, phenomena of, 2, 213
Bark of trees, 293
Barometer, principles of the, 22, 144
Bath-stone, 66
Benzoic acid crystals of, 347
Biennials, 120
Birds, health of, affected by heated air,
Bird-fountains, principles of, 241
Bleaching flowers by acid vapours, 152
Blighted plants, 119
Blood, constituents of the, 49, 299
Blue colour of the sky, 99
Blue vitriol a poison to plants, 116
Boat sunk by a whale, 281
Boiling fountain of Iceland, 35
 point of water, 144
 water, phenomena attendant upon, 351
Bone-ash, 41
 manure, 273
Bones, hardening principle of, 41
 organic and inorganic matters of, 273
Bottle for taking specific gravities, 316
Branches artificially frosted, 347
Brass, chemical nature of, 219
 stones, 291
Bread, experiments upon, 271
 made from sawdust, 285
 wheat, superiority of, 269
Breeces, sea and land, 182
Brine, cooling of, 310
Bromine, properties of, 26
Buildings protected from lightning, 198
Buoyancy of wood on water, 280
Burning lens formed of ice, 333
Calamine, 292
Calcia or lime, an oxide of calcium, 9, 37
Calcined bones, 273
Calcium, the metal of calx or lime, 9, 34
Capacity of bodies for heat, 158
Capillary attraction, 62
Carbon, 6

- Carbon, eduction of from carbonic acid, 140
 ——— escape of during the germination of seeds, 87
 ——— tons of emitted during respiration, 126
 ——— universally present in organic bodies, 47
 Carbonate of lime, 10, 39
 ——— decomposition of by heat and acids, 181
 ——— of potassa, sources of, 282
 Carbonic acid, 9
 ——— balloon inflated by, 289
 ——— composition of, 9
 ——— decomposition of, by plants, 124, 127, 239
 ——— ——— by potassium, 124
 ——— descent of through a tube, 137
 ——— educed from the atmosphere, 130—138
 ——— produced by combustion, 81
 ——— ——— fermentation, 277
 ——— ——— germination, 86
 ——— ——— respiration, 83, 288
 ——— ——— quantity of produced during respiration, 125
 ——— ——— suffocation by, 278
 ——— ——— thermal levity of, 289
 ——— ——— weight of, 278, 288
 Carburetted hydrogen, 247, 393
 Cattle, fodder of, 286
 Ceilings, ascent of hot air towards, 384
 Cereal grasses, vitreous clothing of, 187
 Chalk, decomposed by heat and acids, 181
 Charcoal, sources and uses of, 287, 290
 Charred timbers, 288
 Chemistry, ancient and modern, state of, 14
 ——— depends upon experiment, 7
 ——— exemplifies the wisdom and beneficence of God, 2
 ——— nomenclature of, 5
 ——— objects of, 2
 Chill, injurious effects of, 177
 Chimnies, draught of, 7
 Chlorine, 7
 ——— density of, 259
 ——— eduction of, from common salt, 255
 ——— evolution of, for fumigation, 257
 ——— properties of, 258
 Choke damp, 393
 Chromatic nature of light, 52
 Chyme and chyle, 298
 Clay-iron-stone, 291
 Clay, varieties of, 36, 37
 Climate of the Andes, 171
 Clothing of animals, 397
 Clothing of cereal grasses, 187
 Clouds, classification of the forms of, 97
 ——— electrical, 191, 202
 ——— formation of not satisfactorily explained, 97
 ——— lightning drawn from, 198
 ——— prevent the deposition of dew, 216
 ——— vesicular vapour of, 97
 Coal, importance of as a fuel, 392
 ——— gas, 389
 ——— fires, radiant heat of, 384
 ——— mines, fire damp of, 393
 Cold, application of, to water, 310
 ——— dangerous effects of, on the human body, 364
 ——— expansion of water by, 305
 ——— production of, by the evaporation of ether, 229
 ——— production of, by mixing ice and salt, 400
 ——— production of, by liquefaction, 400
 ——— water lighter than warm, 306
 Coloured clay, 37
 ——— cloths placed in sunshine, 208
 ——— ——— on snow, 34
 Colouring matter removed by charcoal, 288
 Colours of flowers destroyed, 152
 Combustible elements, 4
 Combustion alters the nature of air, 81
 ——— does not destroy, 379
 ——— produces water, 376
 Common salt, varieties of, 265
 Compounds of oxygen and nitrogen, 15
 Concentration of sap in plants, 118
 Condensation evolves heat, 162
 Condiment to food, 267
 Conductors of electricity, 56

- Conductors of heat, 54, 110, 293
 — lightning, 198
Conferva rivularis, the, decomposes carbonic acid, 339
 Confined air a non-conductor of heat, 366
 Congelation of water, 305
 — suspended, of solutions, 305
 Contagious and infectious matters, 252
 Contraction of air by cold, 78
 Convection of heat, 55
 Convective currents in the atmosphere, 55
 — heated water, 305
 Cooling of water, phenomena presented by, 306
 Copper, ores of, 292
 Corinthian capital, origin of the, 115
 Corn harvest of autumn, 267
 Corrosive sublimate a poison to plants, 116
 Cryophorus, the, construction and use of, 178
 Crystals, origin and application of the term, 35
 — deposited upon solid surfaces, 349
 Crystalline form of snow-flakes, 345
 Crystallization, suspension of, 405
 Cubic foot of atmospheric air, 288
 — carbonic acid, 288
 — ice, 314
 — sea water, 314
 — water, 27, 314

 Dampness of building materials, 66
 Dark colours absorb heat, 307
 Darkness affects the functions of vitality, 148
 Dead bodies buried in the ground, 250
 — Sea, water of the, 314
 Deciduous plants, 120
 Decompositions by electricity, 57
 Deep waters never frozen, 309
 Definite weights in which elements combine, 12
 Deliquescent substances, 180
 Density, diminution of, produces cold, 166
 — increase of, evolves heat, 162
 Destruction by fire apparent only, 379
 — of matter is unknown, 379

 Devastation by ballstones, 194
 Dew, phenomena attendant upon the deposition of, 214
 — drops, spherical form of, 224
 Diameter of the earth and altitude of the atmosphere, 21
 Diffusion of smoke through air, 383
 Digestion, changes of food during, 298
 Discovery of oxygen, 242
 Disinfectant power of nitric acid, 253
 — chlorine, 259
 — heat, 262
 Disinfectants, 253
 Dogmas of ancient schoolmen, 13
 Dormant state of seeds, 61
 Double doors and windows, 366
 — rainbow, 106
 Draught of chimnies, 383
 Dust of the ground contains the same elements as the human body, 49

 Earth the, diameter of, and altitude of, the atmosphere around it, 21
 — inclined position of, in its orbit, 211
 — magnitude of the, 410
 — radiation of heat from, 203
 — temperature of, in summer and winter, 109
 Earthy substances are bad conductors of heat, 110
 Earths, composition of, 34
 — specific gravities of, 322
 Educts and products unintentionally confounded, 69
 Electricity, imponderable nature of, 4, 56
 — identity of with lighting, 197
 Elements, 3
 — alphabetical list of, 4
 — atomic, 14
 — definite combinations of, 12
 — definition of the term, 6
 — employment of the term, 14
 — equivalent numbers of, 29
 — imponderable, 4
 — metallic, 4
 — non-metallic, 4
 — organic, 44
 — ponderable, 4
 — proximate, 10
 — smallest combining weights of, 29

- Elements, transition of during germination, 59
 — ultimate, 13
 — of human bodies, 49
 Embers of a wood fire, 283
 English fire-side, chemical philosophy of the, 378
 Enhydrous, definition of the term, 20
 Epidermis, vitreous, of straw, 187
 Equivalent numbers of elements and compounds, 29
 Ermine, 397
 Esquimaux snow-houses, 341
 Ether, evaporation of, produces cold, 229
 Ethiopian, skin of the, not injured by solar heat, 209
 Evaporation, phenomenon of, 72
 — cold produced by, 176, 229
 — during various states of the atmosphere, 174
 — requires heat in all cases, 175
 — water frozen by, 178
 — of water from the leaves of plants, 118
 Evergreens, 120
 Excitation of electricity, 56
 Expansion of air effects diminution of temperature, 168
 — by heat, 366
 — solids, liquids, and gases by heat, 53, 78, 141—146
 — water by cold, 305
 Explosions in coal mines, 393
 Extinction of flame, 394
 Experiment the basis of Chemistry, 2, 7

 Fairy rings, 503
 Fat, 43, 47
 Fermentation, 277
 Fertile soils, analysis of, 41
 Fibrin, 43, 46
 Fire, apparent destruction by, 379
 —, not an element, 14
 Fire-balloon the, illustrates the thermal levity of carbonic acid, 289
 Fire damp of coal mines, 393
 Fire-places, construction of, 384
 Fish-globes, 244
 Fishes, absence of, from mountain-lakes, 235
 —, preservation of, during winter, 334

 Fishes, respiration of, 236, 244
 Flame, ascent of, 381
 — arrested by metallic tissues, 393
 — ceases in confined air, 81
 — on the surface of water, 138
 Floors, cold draught on, 385
 Floation of cold upon hot water, 307
 — of hot upon cold water, 352
 — of liquids upon each other, 318
 Flowers, aroma of, 263
 — colour of, affected by acid vapours, 151
 — drops of water upon, 226
 Foam of a mountain torrent, 238
 Focus of a lens directed into water, 245
 Fold-yard and stable offal as a manure, 274
 Foliage of trees, 121, 294, 303
 Food, changes of, during digestion, 298
 — condiment to, 267
 — elements of, 295
 Footsteps, marks of, on grass, 303
 Forest trees, ashes of, 282
 Four seasons, phenomena of the, 2
 Fragrance after a summer shower, 174
 Frost bitten limbs, 364
 Frosted window pane, 350
 Frosts at the close of autumn, 303
 Frost-smoke, 336
 Freezing mixtures, 179
 — of the sap of trees, 326
 — of water by evaporation, 178
 — point of water, 144, 305, 324
 Frozen provision, 329
Fucus vesiculosus, air contained in the, 243
 Fuel arranged in a fire-grate, 380

 Gases, elementary, 19
 — expand by heat, 145
 — specific gravities of, 323
 — volumes in which they combine, 32
 Gastric juice, 298
 Gazolytes, 19
 Gelatin, 43, 46
 Germination, 58
 — alters the nature of air, 86

- Germination, vital force exerted by, 113
 Glass globes for fish, 244
 Globe of water yields a burning focus, 246
 Gluten, 43, 46, 268
 Graduation of the thermometer, 144
 Grain bearing vegetables, 295
 Granite rocks, disintegration of, 37
 Grape-juice, 277
 Grass, dew-drops upon, 225
 — scorched marks upon, 303
 Grass-plats, radiation from, 217
 Ground ice, formation of, 338
 Grotto del Cane, gas of the, 288
 Growth of a willow tree, 123
 — plants in confined air, 152
 — vegetation during summer, 122
 Gum, 43, 46, 375
 Gun cotton, 286

 Hall, phenomenon of, 346
 Hall-stones, crystalline form of, 194
 Halo round the moon, 107
 Hard water, 25
 Hay harvest, the, facts concerning, 184
 Hay-stacks, heating and firing of, 185
 Heat, 53
 — absorption of by unmetallic surface, 204
 — capacity of bodies for, 158
 — chemical powers of, 53
 — conduction and non-conduction of, 110, 293
 — evolution of, during solidification, 403
 — disinfectant power of, 263
 — expands substances, 53
 — imponderable nature of, 4, 53
 — importance of, 53
 — latent state of, — radiation of, 203
 — reflection of, 203
 — required in all cases of evaporation, 175
 Heating and firing of hay-stacks, 185
 Hoar frost, 346
 — imitated artificially, 347
 Honey-dew, 227
 Hot-air stoves, 386
 Human body, elements of the, 49

 Hydrated, definition of the term, 90
 Hydrochlorate of ammonia, 33
 Hydrochloric acid, 32
 — decomposes carbonate of lime, 131, 137
 Hydrogen, 18, 374
 — adoption of, as a standard of unity, 28
 — combustion of, produces water, 376
 — eduction of, from water, 18, 374
 — inflammability of, 374
 — volume of, contained in water, 377
 Hydrometer for taking specific gravities, 316
 Hygroscopic substances, 180
 Hygrometer, construction and use of the, 228
 Human beings, number of, from the Creation to the present year, 125
 Hyponitrous acid, 15

 Ice, antiseptic power of, 328
 — burning lens formed of, 333
 — cubic foot of, 314
 — expansion attendant upon the formation of, 324
 — floats on water, 310
 — obtained by radiation of heat, 220
 — production of, 306
 — quantity of, thawed by heated oil and water, 161
 — fracture of, in winter, — absorption of heat by thawing, 398
 — artificial, 402
 — mixed with salt produces cold, 402
 — box for the preservation of, 367
 — specific gravity of, 314
 — thawing of, 398
 — temperature of water, resulting from thaw of, 398
 — houses, construction of, 330
 Icicles, formation of, 351
 Ignis fatuus, cause of the, 249
 Illustrations of the art of analysis, 68
 Imperfect conductors of heat, 54
 Imperfect conductors of electricity, 64
 Incombustible elements, 4
 Indestructibility of matter, 378
 Inflammable gas of stagnant waters, 247

- Instantaneous crystallization, 404
 Insalubrious districts, 232
 Inundation by rivers, 103
 Inundations during hay harvest, 184
 Iodide of starch, 270
 Iodine properties, 25
 Iron, elementary nature of, 6
 Iron vessels ruptured by water in freezing, 324
 Isomerism and isomeric bodies, 48

 Jars of water cooled in warm climates, 176

 Kingdoms, organic, mutually dependent, 51

 Lake on a mountain summit, 235
 Lakes, freezing of, 307
 Latent heat of water, 399
 Lead, compression of, evolves heat, 162
 Leaves absorb aqueous vapour, 119
 — autumnal tints of, 303
 — drops of water upon, 226
 — fall of in autumn, 304
 — form of, in different latitudes, 121
 — transpire aqueous vapour, 118
 Light, analysis of, 52
 — chemical powers of, 52
 — imponderable nature of, 4, 51
 — importance of, 52
 — influence of, on vegetation, 147
 — predilection of plants for, 147
 — refraction of by heated air, 154
 — spontaneous, of insects, plants, &c., 249
 Lightning, distance of, calculated, 191
 — drawn from clouds, 198
 — flash of, 56
 — identity of, with electricity, 197
 — incites the formation of nitric acid from air, 17
 — phenomenon of, 190—195
 Lightning-conductors, 198
 Lignin, 43, 46, 278, 293
 — non-conducting power of, 294
 Lime, properties of, 11, 37, 274
 Lime-manure, 274

 Limestone rocks, vegetation upon, 78
 Liquids expand by heat, 142
 — floating upon each other, 318
 — specific gravity of, 27
 — weight of, 315
 Liquefaction produces cold,
 Litharge, 256
 Lungs, air inhaled by the, 83

 Magnesia, properties of, 26
 Magnesium the metal of magnesia, 26, 34
 Malachite, 292
 Malaria, 251
 Man, size of, in comparison with that of the earth, 411
 Manures, 7
 Marble a compound, 8
 March winds, 96
 Marshes, inflammable gas of, 247
 Marsh-miasma, 251
 Masses, bulks, and volumes, 5
 Matter is indestructible,
 Matting prevents plants from cold, 218
 Maximum density of water, 306
 Medicine an exalted science, 297
 Mephitic results of respiration, 84
 Mercury, specific gravity of, 315
 — weight of, supported by the atmosphere, 22
 Metallic elements, 4
 — ores, reduction of, 290
 — surfaces reflect heat, 203
 Metallurgy, ancient processes of, 290
 Metals, anciently known, 290
 — conduction of heat by, 293
 — expansion of, by heat, 141
 — oxidation of, 88
 — specific gravities of, 322
 Meteoric iron, 292
 Milk of lime, 134
 Mineral waters, 25
 Mist artificially produced, 168
 — at sunrise, 222
 Monk and cow, the, 182
 Moonlight supposed to favour corruption, 220
 Mountain lakes, 235
 Mount Etna, preservation of snow upon, 113
 Must of grapes, 277

 Naples, preservation of snow at, 188
 Naptha, 136
 Native sulphuric acid, 265
 Natron of the ancients, 264

- Nitrate of ammonia, 33
 Nitrate of potassa, 253, 264
 Nitre, ancient and modern, 264
 Nitric acid, composition of, 15
 — disinfecting by, 253
 — formation of, incited by electricity, 17
 — properties of, 253
 Nitric oxide, 15
 Nitrogen, 4, 15, 92
 — weight of, in the atmosphere, 21
 — volume of, in the atmosphere, 91
 — presence of, in wholesome food, 297
 — presence of, in organic bodies, 44
 — mixture of, with oxygen, 16
 — eduction of, from atmospheric air, 88
 — compounds of, with oxygen, 15, 31
 — compound of, with hydrogen, 33
 Nitrous acid, 15
 Nitrous oxide, 15
 Nomenclature chemical, 5
 Non-conductors of electricity, 56
 — of heat, 54
 Non-metallic elements, 4
 Non-supporters of combustion, 5
 Nutritious food, 297
 Nuclei, action of, on the accretion of crystals, 349

 Oil, capacity of, for heat, 158
 Open fires, warming by, 384
 Ores of copper, 291, 292
 — iron, 291
 — zinc, 292
 Organic bodies, analysis of, 42
 — invariably contain carbon, 47
 — isomeric, 48
 — proximate elements of, 43
 — tabular statements of their composition, 44, 45
 — ultimate elements, 42
 Organic kingdoms, mutual dependence of the, 244
 Oxalic acid, 30
 Oxide of mercury, 89, 93
 Oxygen, derivation of, 9
 — discovery of, 242
 — evolution of, from carbonic acid, 241

 Oxygen evolution of, by aquatic plants, 242, 423
 — weight of, in the atmosphere, 21
 — volume of, in water, 377
 — volume of, in the atmosphere, 91
 — combination of, with hydrogen, 19

 Pavements, removal of snow from, 401
 Perennials, 120
 Petrifying springs, 40
 Philosophical knowledge enjoined in Scripture, 98
 Phosphorescence, phenomena of, 250
 Phosphates, 39
 — in soils, 41
 Phosphate of lime, sources and properties, 40
 Phosphoric acid, 37, 39
 Phosphorus, combustion of, in confined air, 90
 — sources and properties, 39
 Physical states of ponderable matter, 5
 Plants, aliment of, 124
 — annual, 120
 — biennial, 120
 — blighted, 119
 — carbon contained in, 123
 — deciduous, 120
 — decompose carbonic acid, 124, 127
 — diverted from their natural course of growth, 114
 — drooping by heat, 119
 — during growth enclose solid obstacles, 115
 — evaporation of water from their leaves, 118
 — evergreen, 120
 — existence of, 301
 — frost-bitten, 221
 — growth of, in confined air, 152
 — growth of, in darkness, 148
 — growth of, in light, 147
 — influenced by light, 147
 — injury of, by acid vapours, 150
 — perennial, 120
 — poisoned by metallic and other compounds, 116
 — predilection of, for light, 147
 — radiating powers of, 215

Plants, radicle fibres of, 116
 ——— sap of, 117, 272
 ——— succulent, 117, 119
 ——— tropical, 121
 Plumage of birds affected by light,
 149
 ——— water-fowl, 227
 Poisons, action of, on plants, 116
 Potash, derivation of, 26
 Potassa, composition of, 26
 Potassium decomposes carbonic
 acid, 124, 139
 ——— decomposes water, 138
 ——— properties of, 26
 Pressure of the atmosphere, 22
 Primary combinations, 12
 Prismatic colours of solar light, 52
 Produce of seeds, 300
 Products of respiration, 83
 ——— of combustion, 81
 Proverbs concerning natural pheno-
 mena, 72, 96, 102, 106
 Provision preserved by freezing, 329
 Prussic acid a poison to plants, 117
 Proximate elements, 10, 43
 Purification of air by growing plants,
 126—130
 Putrefaction supposed to be hastened
 by moonlight, 220
 Putrefactive changes, 50
 ——— hastened by water,
 183
 Putrefactive taint removed by chlo-
 rine, 259

 Quick lime, 2, 132

 Radiating powers of plants, 215
 Radiation, phenomenon of, 203
 Radiators of heat, 54
 Radicle and plumula of seeds, 59
 Rainbow, phenomenon of the, 52,
 104
 Rain-drops, spherical form of, 225
 Rain-water, 25
 Rainless districts, 103
 Rain, quantity of, in various parts of
 the world, 103
 Rarefaction produces cold, 166
 Recovery, means of, from apparent
 death by cold, 364
 Red colour of the sky, 100
 Red iron-stone, 291
 Red lead, 256
 Red precipitate a source of oxygen,
 89, 93
 Red snow of the Arctic regions, 345
 Reduction of metallic ores by char-
 coal, 291
 Reflectors of heat, 54

Refraction of light, 59
 Region of clouds, 97
 Respiration alters the nature of air,
 83
 ——— quantity of carbonic acid
 produced during, 35
 ——— removal of the result of,
 84, 423
 Respiration of fishes, 236, 244, 423
 Restoration of vitiated air by plants
 126—130
 River-water, 25
 Rock-salt a compound, 7
 Rocks, degradation or decay of, 326
 Rooms, ventilation of, 387
 ——— warming of, 386

 Safety during thunder-storms, 195
 Safety-lamps, 394
 Saline matters affect the congelation
 of water, 309
 ——— of sea-water,
 25
 Salt lakes, 175
 Sandstone rocks, vegetation upon,
 78
 Sap of vegetables, 117, 272
 ——— freezing of, 326
 Sawdust, bread made from, 285
 Sea-weed a hygroscopic, 181
 Sea-water, 25
 ——— congelation of, 307
 Sea and land breezes, 182
 Secondary combinations, 12
 Seconds, number of, from the Crea-
 tion to the present year, 128
 Seeds, dormant state of, 61
 ——— elements of, 59
 ——— germination of, 59
 ——— part with carbon during ger-
 mination, 67
 ——— produce of, 300
 ——— radicle and plumula of, 59
 Showers of spring, 72, 74
 Silica, amorphous forms, 35
 ——— crystalline form of, 35
 ——— insolubility of, 35
 ——— presence of, in cereal grasses,
 35
 ——— in rocks and soils, 35
 ——— solubility of, 35
 ——— sources and varieties of, 34
 Silicium the metal of silica, or flint,
 34
 Single rainbow, 105
 Sky, colours of the, 99
 Skin of the Ethiopian not injured
 by solar heat, 209
 Skins of animals affected by light,
 149

- Slaked lime, 132
 Smoke, descent of, 385
 Snow, crystalline form of, 345
 — fall and properties of, 340
 — non-conducting power of, 121
 — phenomenon of, 340
 — preservation of, on Mount Etna, 113
 — at Naples, 189
 — protects vegetation, 341
 — thawing of, 341
 Snow-houses, construction of, 341
 Soap earth, 265
 Soda, 8
 — carbonate of, 264
 Sodium, 8
 — chloride of, 8
 — decomposes water, 371
 Soft water, 25
 Soils, absorption of water by, 61, 75
 — analysis of, 41, 67
 — heating and cooling of, 155
 — tabular statement of three analyses of, 70
 — varieties of, 70
 Solar heat, absorption and retention of, 207
 — adjusted to the earth and its productions, 172
 Solidification evolves heat, 403
 Solid obstacles removed by germination, 113
 Solids expand by heat, 141
 — liquids, gases, and vapours, 5
 — specific gravity of, 27
 Solution, 65
 Sound of thunder, 56
 Specific gravity defined, 23, 313
 — of air, gases, and vapours, 23, 323
 — of the earths, 322
 — of liquids and solids, 27
 — of metals, 322
 — of water, 27, 313
 Specific-gravity bottle, 316
 Spherical and spheroidal drops of water, 225
 Spontaneous light of insects, plants, &c., 249
 Spring phenomena of, 2, 58
 Springs of water do not freeze, 109
 Spring water, 25
 Stalactites, formation of, 40
 Starch, 43, 46, 269
 Steam, production of, 407
 Steam, solution of, in air, 382
 Steam engine, 359
 Stout, skin of the, 397
 Stoves, warming by, 387
 Straw, vitreous epidermis of, 187
 Sublimation, process of, 347
 Succulent plants, 117, 119
 Suffocation by carbonic acid, 278
 Sugar, 43, 46, 275
 — obtained from lignin, 386
 Sulphate of lime, varieties and properties of, 40
 Sulphates, 39
 Sulphites, 39
 Sulphur, sources and properties of, 38
 Sulphuretted hydrogen, 39
 Sulphuric acid, 39, 265
 Sulphurous acid, 39
 Summer, increase of vegetable growth during, 122
 — phenomena of, 2, 122
 — temperature of the earth during, 109
 Sun-burn on a fish, 245
 Sun-dried hay contains water, 184
 Sun-stroke, physical cause of the, 210
 Sunrise, mist at, 223
 Supporters of combustion 4
 Swan, plumage of the, 227
 Synthesis of atmospheric air, 95
 — of water, 19, 372, 377
 Tarnishing of heated metals, 88
 Temperature, equalization of, throughout the globe, 211
 Temperature of the earth in summer and winter, 109
 Thatch a bad conductor of heat, 188
 Thaw produces cold, 401
 Thawing, phenomena of, 400
 Thawing of snow, 341
 Theory and hypothesis contrasted, 108
 Thermal levity of carbonic acid produced during combustion, 269
 — matters exhaled during respiration, 84
 Thermometer, principle of, its construction and graduation, 143
 Thermometric liquids, 365
 Thunder clouds, 191
 Thunder-storm, the forebodings of the, 189
 — phenomena of the, 56, 189—196
 — precautions for personal safety during, 195
 Tinder inflamed by the compression of air, 164

- Tons of air around the earth, 21
 — of carbon emitted during respiration, 126
 Transparent substances incapable of heating by the solar rays, 55
 Transpiration of water from vegetables, 118
 Transplanting, precautions during, 116
 Tranquillity of the air essential to the deposition of dew, 216
 Transition of water into ice, 308
 Trees, sap of, frozen during winter, 326
 — temperature of, in hot and cold weather, 294
 Tropical climates, breezes of, 182
 — plants, 121
 Turmeric paper a test of alkaline substances, 133

 Ultimate elements, 10
 — of human bodies, 49
 — of organic bodies, 42
 — of the atmosphere, 20, 42
 Uniformity in the constitution of the atmosphere, 16
 Unmetallic surfaces absorb heat, 204

Vallisneria spiralis, the utility of, in fish globes, 243, 423
 Vegetables, ashes of, 282
 — functions of, influenced by light, 147
 — growth of, during summer, 122
 Vegetation affected by light, 147
 — decomposes carbonic acid, 126
 — injured by acid vapours, 150
 — limit of, 121
 — protected by snow, 341
 — secretes carbon from the atmosphere, 124
 — supported by water, 71—
 — upon rocks, 65
 Ventilation, 387
 Vesicular vapour, 97
 Vessels broken by frost, 325
 Vinegar, production of, 284
 Vital force exerted by germination, 113
 Vitiated air restored by plants, 126, 130

 Vitreous ashes of hay, 185
 — clothing of cereal grasses, 187
 Volumes in which gases and vapours combine, 32
 — of oxygen and hydrogen contained in water, 377
 — of oxygen and nitrogen contained in air, 91

 Warming apartments, 386
 Water, 18, 28
 — absorption of, by soils, 61, 75
 — adoption of, as a standard for specific gravities, 27, 314
 — aëration of, necessary for the life of aquatic beings, 236
 — apparently the sole aliment of plants, 124
 — boiling of, by artificial heat, 351
 — boiling-point of, 144
 — burning focus obtained by, 246
 — capacity of, for heat, 158
 — cold floats on warm, 307
 — composition of, 18
 — crystallization of, in small cavities, 337
 — cubic foot of, 314
 — decomposition of, 371, 374
 — decomposition of, by potassium, 138, 373
 — evaporation of, at low temperatures, 180
 — evaporation of, from a surface in various states of the atmosphere, 174
 — evaporation of, from vegetables, 118
 — evaporation of, produces cold, 176
 — expansion of, by cold, 305
 — expansion of, by freezing, 324
 — fall of, through a vacuum, 238
 — freezing point of, 27, 144, 306
 — freezing point of, lowered by saline matters, 309
 — frozen by its own evaporation, 178
 — habits of, with artificial heat, 351
 — hastens putrefaction, 183
 — latent heat of, 399
 — maximum density of, 306
 — never found pure, 27
 — not an element, 14
 — not heated by a burning lens, 245
 — non-conducting power of, 351